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A STUDY OF NITRATE AND MINERAL CONSTITUENTS FROM TILE DRAINAGE IN THE SAN JOAQUIN VALLEY, CALIFORNIA

L. D. Doneen

California University
Davis, California

November 1966

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CENTRAL PACIFIC RIVER BASINS PROJECT

A STUDY OF NITRATE AND MINERAL CONSTITUENTS FROM TILE DRAINAGE IN THE SAN JOAQUIN VALLEY, CALIFORNIA

By

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A STUDY OF NITRATE AND MINERAL CONSTITUENTS FROM TILE DRAINAGE IN THE SAN JOAQUIN VALLEY, CALIFORNIA

By

L. D. Doneen

Professor of Water Science
Department of Water Science and Engineering
University of California, Davis

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A Study of Nitrate and Mineral Constituents from Tile Drainage in the San Joaquin Valley, California

INTRODUCTION

The following investigation is a cooperative project between the Central Pacific River Basin Project, Federal Water Pollution Control Administration and the Department of Water Science and Engineering, University of California, Davis. It was supported in part by a purchase order to the Regents of the University of California from the Federal Water Pollution Control Administration and by the Water Resources Center, University of California. The California Department of Water Resources (DWR), San Joaquin District, provided excellent assistance in the field investigations.

The basin soils of the San Joaquin Valley and particularly those in the trough of the Valley are imperfectly drained, resulting in a high water table, partly natural, but accentuated in recent years by irrigation. This contributes to the salt accumulation in the water table, and soil profile, from natural drainage into these basin soils and/or brought in by irrigation water. Maintenance of a favorable moisture regime (1) and a low salinity level for plant growth requires some leaching of the soil below the depth of the rooting zone (2) because surface evaporation and transpiration by plants remove the soil moisture but leave the salts behind to accumulate in the soil and water. Farm tile drains were installed to remove the excess water and leach the salts from the rooting zone of plants, providing a better soil environment for crop production.

The first drainage systems were installed about 1950, and a large number between 1955 and 1961 (3). The farm drainage systems have continued to increase in numbers, and the rate will probably accelerate in the near future, particularly with the advent of imported water from the San Luis and the Feather River projects of the U. S. Bureau of Reclamation and the California State Department of Water Resources, respectively.

The total salinity in the effluent from many of the drains remained at a high concentration after the soil was leached for a number of years. Furthermore, the nitrate-nitrogen and boron concentration was extremely high in certain drains and tending to remain so after considerable leaching.

The object of this study is to determine the origin of the salines particularly nitrate-nitrogen and its source, as from irrigation water, fertilizers, the soil profile, or a natural accumulation in the ground water. For this purpose three drainage areas were selected where the salinity and nitrates in the effluent, according to DWR tests, were present in appreciable quantities.

LOCATION AND SOIL

The three drainage fields listed as DS, GH, and GT are located in the trough of the San Joaquin Valley within a distance of 3 miles. The soils for DS and GH are classified as Panoche silty clay (4) and in 1942 was described as slightly alkali. GT field is a Panoche loam, also slightly alkali.

The Panoche soils are of recently deposited alluvium originating from the softly consolidated calcareous gypsiferous sandstones and shales of the central and southern coast ranges. They are without distinct horizons, but generally stratified with deposits of coarse and fine material. They usually contain 2 to 3 percent lime and may contain gypsum crystals between the depth of 3 and 5 feet. Surface and internal drainage is usually good.

Two locations - non-irrigated without artificial drainage - were selected for comparison with the irrigated and drained areas. These are listed as GH-Vi and PG. The former is in the area listed above and has the same soil type and conditions, while the latter is about 12 miles away with soil classified as a Panoche sandy loam and moderately alkali.

PROCEDURE

Field

Soil profile was sampled at two locations at opposite ends of the field. At each location three soil samples were taken with an auger, about 15 feet apart in foot increments, into the saturated soil or water

table – usually 6 to 8 feet in depth. The three samples from each depth were combined in the field, placed in plastic bags and treated with a soil fumigant D-D (dichloropropanes and dichloropropenes). (The author has tested this material and used it many times to prevent nitrification in soil samples). The fields were sampled a second time one or two months later at approximately the same location following the above procedure. Thus 4 composited samples from each field for each soil depth were obtained for analyses. The un-irrigated soils, GH-Vi and PG, were sampled at only one location on one date. The soil samples were taken to Davis, moisture content determined, spread thinly on a greenhouse bench, air dried, and then ground to pass through a 2mm screen for chemical analyses.

Effluent from the three drainage systems was measured about three times weekly with a bucket and stop watch by DWR personnel. Periodically the effluent was sampled and sent to Davis for analyses. In addition DWR provided some analyses of the drainage water, especially for nitrates.

Farm practice: The acreage, depth and spacing of the tile drains, crops grown, quantity of irrigation water applied and the fertilizer practice for the present season, and for several past years were obtained from the owner or operator of the property.

Laboratory

Soil analyses: The chemical analyses were those developed and in general use for saline and alkali soils, irrigation, and drainage water (2). The salinity and soluble ions of the soil were obtained by preparing a saturated paste with distilled water and allowing it to set overnight to, approximately, reach equilibrium with the slightly soluble material in the soil. Part of the solution from the paste is extracted by vacuum and this solution is known as the saturation extract (2) for the chemical analyses of the soluble ions in the soil. The water content of the saturated paste is usually slightly higher than the saturated soil in the field because of the lower volume weight and greater porosity. For many of the heavier (clay) soils the saturation extract is about twice the field capacity (FC), i.e., the moisture held by the soil after most of the downward movement has taken place following a rain or any irrigation.

The following analyses were made on the saturation extract: electrical conductivity ($EC \times 10^3$), bicarbonates (HCO_3), chloride (Cl), sulfate (SO_4), nitrate (NO_3), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), and boron (B).

Gypsum content of the soil was determined when Ca and SO_4 ion concentration approached solubility values in the saturation extract.

Irrigation water and drainage effluent analyses: The same constituents were analyzed as listed above for the saturation extract.

RESULTS FROM INDIVIDUAL FIELDS AND LOCATIONS

DS - Drain Field

The field is a rectangular area of 150 acres. The drainage system was installed in 1957 and 1959 with a spacing of 400 feet between lateral drains at an average depth of 6.9 feet.

Farm management: Since 1962 records are available for the crop grown, total irrigation water and nitrogen applied to the area, Table 1. For 1966 a detailed application of water and fertilizer applied

Table 1

Historical Management for 4 Years on the DS Field

Year	Crop	Acreage	Water applied ac.ft/ac./yr.	Nitrogen Fertilizer lbs - N/ac./yr.	Ave.
1962	cotton	105	2.4	195	
	rice	45	8.5	106	168
1963	Barley	45	0.6	80	
	cotton	60	2.0	200	124
	rice	45	9.4	70	
1964	cotton	45	2.5	200	
	rice & barley	60	7.2	140	176
	cotton	45	2.4	200	
1965	cotton	43	1.9	160	
	barley & lettuce	74	3.4	246	202
	cotton	33	2.1	160	

is listed in Table 2. The consumptive use of water by cotton in this area is about 2.0 to 2.2 ac. ft/acre per season, while barley and safflower being essentially winter and spring crops and require less irrigation water to supplement the rainfall. Therefore the amount of irrigation water required will depend on the rainfall and residual moisture in the soil from the previous crop. Rice is continuously flooded with water during the summer months. Consequently its water requirements are high not only from transpiration, but also from evaporation of the water surface and large quantities percolating through the soil to the drain lines (3). In 1966, only 1.7 ac. ft/acre of water has been applied to the cotton, Table 2, but probably one additional irrigation will be applied in September. For the past 5 years an average of 169 pounds of nitrogen fertilizer has been applied to this field, Tables 1 and 2.

Table 2

Application of Water and Fertilizer for 1966 and DS Field

		Irrigation		Fertilizer		
			Date			
Crop	Acreage	ac.ft/ac.	from - to	lbs.-N/ac.	Type	Date
Cotton	130	0.4	2/25-3/5	160	NH[1/]	3/1
		0.5	6/15-6/24	60[2/]	NH SO	5/15
		0.4	7/18-7/26			
		0.4	8/16-8/23			
Safflower	20	0.6	3/5 -3/7	80	NH SO	2/1

1/ Anhydrous ammonia ave. 177

2/ 70 acres of the 130 acre field fertilized

Soil salinity: Analyses of the saturation extract of the soil profile by foot intervals to a depth of 7 feet are given in Table 3. As expected the salinity increases with depth. Although sample locations A and B were at opposite ends of the field, they show variations in salt content; there also occurred wide differences in salinity between the dates of sampling at approximately the same locations. For example, location A

Table 3

Analyses of the Saturation Extract for Soil Profiles of Field DS for Two Sampling Dates and Locations at the Opposite End of the Field, A & B

Depth feet	ECX10^3	Boron ppm	Milliequivalents per Liter								
			HCO_3	Cl	SO_4	NO_3	Na	Ca	Mg	K	Total
Site 1, sampled 6/15, Location A											
0-1	1.5	0.3	3.2	5.8	5.0	0.37	4.8	7.0	1.7	0.5	14.0
1-2	0.8	0.2	2.7	3.8	1.9	0.73	3.8	3.0	1.2	0.3	8.3
2-3	1.3	0.7	2.7	5.5	4.3	0.98	6.3	5.0	1.0	0.2	12.5
3-4	1.8	0.8	2.2	4.7	11.7	0.93	9.5	7.0	1.9	0.3	18.7
4-5	1.5	0.8	2.2	5.0	7.2	1.00	7.8	4.5	1.7	0.3	14.3
5-6	2.8	1.7	2.7	7.8	18.9	0.82	17.4	10.0	2.3	0.4	30.1
6-7	4.2	2.0	2.7	9.8	36.4	1.21	25.8	16.0	7.0	0.7	49.5
Site 2, sampled 6/15, Location B											
0-1	1.6	0.7	3.8	6.1	6.5	0.15	7.5	6.5	1.7	0.5	16.2
1-2	2.0	0.8	2.2	8.3	9.1	1.50	12.1	6.0	1.7	0.7	20.5
2-3	4.4	2.3	2.2	14.0	31.4	0.77	33.9	8.0	3.0	0.8	45.7
3-4	8.2	5.4	2.2	14.8	87.0	0.71	72.2	22.0	9.3	0.8	104.3
4-5	9.8	1.4	1.6	10.9	111.3	0.55	84.3	24.0	13.3	0.8	122.4
5-6	9.8	1.5	2.2	9.8	114.7	0.64	87.0	24.0	14.2	0.8	126.0
6-7	9.8	9.4	1.6	14.5	108.3	1.07	84.3	25.0	14.2	1.0	124.5
Site 3, sampled 7/18, Location A											
0-1	1.4	0.5	3.2	3.8	6.2	0.38	6.5	6.0	1.7	0.5	14.7
1-2	1.7	0.7	3.2	4.2	8.2	1.93	8.6	6.0	2.0	0.2	16.8
2-3	2.8	1.2	2.7	8.9	16.8	1.61	19.6	7.0	2.2	0.3	29.1
3-4	7.6	3.9	1.6	16.0	85.7	0.55	60.9	27.0	13.7	0.7	102.3
4-5	5.6	6.9	1.6	15.1	107.6	0.50	80.0	27.0	15.0	0.7	122.7
5-6	8.6	7.1	1.6	8.3	106.6	0.45	73.0	27.0	14.3	0.6	114.9
6-7	6.6	4.9	1.6	7.2	82.8	0.54	50.2	27.0	13.7	0.6	91.5
Site 4, sampled 7/18, Location B											
0-1	1.4	0.2	3.2	4.1	7.4	0.11	5.5	6.5	1.9	0.4	14.3
1-2	1.1	0.3	2.7	3.6	5.8	0.14	5.5	4.5	1.4	0.2	11.6
2-3	1.1	0.5	2.2	3.6	5.5	0.57	6.5	3.5	0.8	0.2	11.0
3-4	2.5	1.5	1.6	2.7	24.5	0.42	14.5	10.5	3.4	0.3	28.7
4-5	3.9	1.3	1.6	3.8	45.8	0.32	15.8	25.0	9.2	0.5	50.5
5-6	3.8	1.1	1.6	4.7	44.8	0.34	15.8	25.0	8.7	0.5	50.0
6-7	4.0	1.1	1.6	7.2	46.2	0.45	15.2	29.0	9.8	0.6	54.6

sampled on June 15 has a lower salt content in the profile than the later sampling on July 18. This difference is also noted for location B where the first sampling on June 15 is higher in salinity than at the later date of July 18. That soil salinity may vary greatly in short distances and sometimes within a few feet is well known to workers concerned with field salinity.

In this field high boron concentration is associated with high salinity. Sulfate is the predominant anion and at the higher concentrations indicates the presence of gypsum. Where salinity occurs sodium is high in concentration due to the limited solubility of $Ca\ SO_4 \cdot 2H_2O$.

The moisture characteristics, nitrogen, and salts are given in Table 4 by foot increments of the profile for the four soil samplings. The field moisture is relatively uniform for the four profiles - containing about 30 inches in depth of water for a 7 foot depth. Except for the surface two feet where evapotranspiration has occurred, the soils are approximately at field capacity (FC). However, the seventh foot of soil and to some degree the sixth foot is saturated, or partly saturated, from the ground water table; therefore the soil moisture percentages are probably above the FC for this depth. Because of the compensating factor of high moisture in the lower two feet for the low moisture in the surface two feet of soil, the 30 inch depth of water represents approximately the soil moisture content at field capacity.

The total pounds of nitrate nitrogen are relatively high in the profiles for three sites but appreciably lower at site 4. This low nitrogen content is probably due to increased leaching as the soil profile is somewhat lighter (less clay) than at the other sampling sites.

The salinity is low except at the depths where gypsum occurs. No gypsum was found at site 1 and only moderate amounts in the lower 3 feet at site 4. The other 2 sites, 2 and 3, contained rather large amounts of gypsum in the lower 4 feet of the profile which has a marked influence on the salinity of the saturation extract, Table 3.

Effluent composition and drain discharge. From June 6 to August 31, 10 samples of effluent were analyzed and all constituents remained relatively uniform during this period, Table 5. The salinity and boron content of the drainage water is high with predominating ions being sulfate and sodium. Of the total cations, sodium constitutes 64 percent. This is

Table 4

Profile Distribution of Field Moisture, Saturation Percentage, Nitrogen as Nitrates, and Salts on the Oven Dry Bases for Field DS

Depth Feet	Field Moisture %	Field Moisture Depth ac.in.	Saturation[1] %	lbs NO_3-N[2] ac.ft.	me per 100 gr soil Soluble Salt	me per 100 gr soil Gypsum
			Site 1, sampled 6/15, Location A			
0-1	23.7	3.5	77.1	20.9	1.1	
1-2	28.1	4.2	61.8	21.5	0.5	
2-3	30.0	4.5	84.5	39.5	1.1	
3-4	29.0	4.3	64.9	28.8	1.2	
4-5	29.3	4.4	61.5	29.3	0.9	
5-6	27.6	4.2	50.2	19.8	1.5	
6-7	33.0	4.9	49.3	28.3	2.4	
Total		30.0		188.1	8.7	
			Site 2, sampled 6/15, Location B			
0-1	20.9	3.1	58.8	4.2	0.9	
1-2	23.1	3.5	56.7	40.4	1.2	
2-3	37.7	5.7	96.2	35.2	4.6	
3-4	32.4	4.9	82.8	28.0	8.6	13.7
4-5	29.9	4.5	91.2	20.9	11.2	31.4
5-6	29.1	4.4	86.5	26.3	13.0	55.1
6-7	29.5	4.4	59.7	30.4	7.4	31.8
Total		30.5		185.4	46.9	147.0
			Site 3, sampled 7/18, Location A			
0-1	19.0	2.8	60.0	25.1	0.9	
1-2	25.4	3.8	55.3	50.8	0.9	
2-3	39.5	5.9	92.8	71.0	2.7	
3-4	33.8	5.1	83.2	21.8	8.5	68.9
4-5	30.1	4.5	81.0	19.2	9.9	35.5
5-6	28.1	4.2	75.7	16.2	8.7	43.9
6-7	33.5	5.0	55.9	14.3	5.1	25.6
Total		31.4		218.3	36.7	173.9
			Site 4, sampled 7/18, Location B			
0-1	21.2	3.2	68.1	3.5	1.0	
1-2	24.6	3.7	68.8	4.6	0.8	
2-3	30.2	4.5	68.8	18.6	0.8	
3-4	29.4	4.4	67.7	13.5	1.9	
4-5	31.2	4.7	67.0	10.2	3.4	6.8
5-6	30.8	4.6	60.1	9.7	3.0	6.1
6-7	31.3	4.7	55.6	11.9	3.0	5.0
Total		29.8		72.0	13.9	17.9

1/ Pore volume saturation under field conditions ± 52.8%

2/ Acre foot soil = approximately 3.4 million pounds

Table 5

Analyses of the Drainage Effluent for Various Dates, Ground and Irrigation Water for DS Field

Date 1966	ECX10^3	Boron ppm	Milliequivalents per Liter								Total Cations
			HCO_3	Cl	SO_4	NO_3	Na	Ca	Mg	K	
			Drainage Water								
6/6*	9.6	16.0	4.6	20.3	96.6	3.40	80.9	23.2	20.4	0.2	124.7
6/15	10.0	14.0	5.9	21.3	99.2	3.14	81.3	22.0	24.3	0.7	128.3
6/30	8.9	9.2	5.9	19.6	87.9	3.14	75.6	19.0	20.3	0.7	115.6
7/6*	9.3	14.0	4.8	11.2	90.6	2.00	73.5	22.5	20.0	0.2	116.2
7/12	9.8	12.4	7.1	21.3	95.8	3.36	81.3	20.0	24.3	0.8	126.4
7/18	9.6	13.8	5.4	21.9	97.5	3.64	83.5	20.0	23.3	0.4	127.2
8/2	9.6	14.0	4.8	20.2	94.9	2.86	75.6	21.0	24.7	0.4	121.7
8/10*	9.9		4.4	20.6		4.52	87.0	24.0			
8/18	9.9	14.0	4.3	21.3	98.5	2.71	78.3	23.0	24.7	0.4	126.4
8/31	10.2	14.4	4.8	20.7	100.1	3.07	78.3	24.0	25.5	0.4	128.2
Ave.	9.7	13.5	5.2	19.8	95.7	3.18	79.5	21.9	23.0	0.5	124.9
			Ground Water								
7/18A	8.4					1.32					
7/18B	4.5					0.66					
			Irrigation Water								
8/18	0.71	0.1	1.6	3.7	1.4	0.12	3.7	1.1	1.6	0.2	6.6

* Analyzed by Department of Water Resources

in line with previous work where gypsum occurs in the subsoil (5). However, the sulfate constitutes about 77 percent of the anions, and is principally derived from gypsum, as the irrigation water is low. The relatively low calcium and magnesium are due to the limited solubility of gypsum and exchange equilibrium with the clay. Since this drainage system has been installed 8 years, it can be assumed that most of the original chlorides (accumulated before installation of drains) have been removed by leaching and those present in the effluent are, essentially, concentrated from the irrigation water.

The Nitrate-Nitrogen is high in the effluent with an average of 3.18 me/L. Two ground water samples were collected from the bottom of the holes for soil sampling and the results are given in Table 5. The average of the 2 samples is 1 me/L of nitrate or about a third of the concentration in the effluent. This would indicate that most of the nitrates in the effluent are originating from the soil profile above the tile drain.or from a deeper depth in the water table. However 2 samples are not sufficient evidence to categorically draw this conclusion. Nevertheless, nitrate salts are soluble and freely move with the water and no doubt

some of them in the ground water prior to draining the field, have been removed by lowering the water table and leaching.

A sample of irrigation water from the supply canal was obtained on August 18 and the analysis is given at the bottom of Table 5. Although only one sampling was made, the electrical conductance of this sample is in general agreement with 6 made by DWR during the summer, therefore it is assumed the analysis is representative of the water quality used for irrigation.

From April 12 to August 30, the discharge from the tile system was measured and a hydrograph of the results plotted in Figure 1. The irrigation in June produced a large tile flow while the irrigations in July and August resulted in small effluent discharge. The June application was made while the cottom plants were small, using only a small amount of the available moisture, whereas in the latter two irrigations the plants were large covering the ground and transpiration rates were high; consequently, these irrigations essentially replenished the soil moisture supply and only a small increase in drainage was noted. Measurement made in September showed a tapering off of flow with about 14 gpm by the first week of October.

The nitrate nitrogen and chloride content of the effluent is plotted in relation to the flow from the tile system, Figure 1. No correlation is observed between the flow and the concentration of these soluble ions.

GH-Drain Field

The area covers 255 acres with the drainage system installed in 1963-65 at an average depth of 5.9 feet with spacing between lateral drains of 300 feet.

Farm Management: The crops grown, the irrigation water, and fertilizer applied to the area from 1962 to 1965 are given in Table 6 and in greater detail for 1966 in Table 7. The consumptive use of water by tomatoes will be about the same as cottom - 2.0 to 2.2 ac. ft/acre. Large quantities of water are applied to lettuce and bell peppers although the consumptive use is much smaller than for cotton or tomatoes. Much of this water is applied during the germination and seedling period when it is necessary to keep the top of the beds moist to establish the crop and develop a root system. Consequently, more leaching of the soil occurs at this time than for most field crops. Over the past few years less nitrogen has been applied

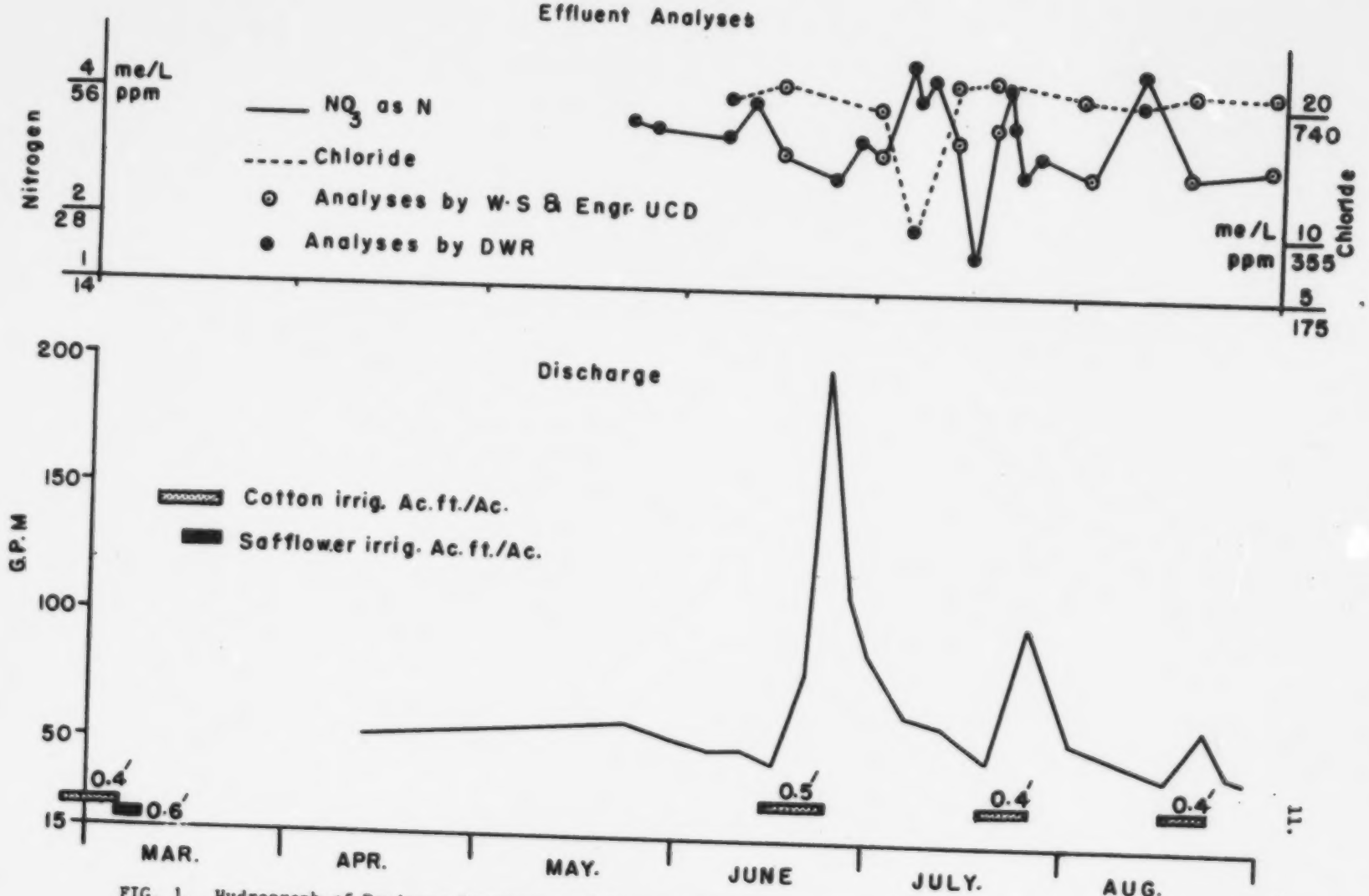

FIG. 1. Hydrograph of Drainage Discharge and Nitrate-Chloride Concentration of Effluent for DS Field.

Table 6

Historical Management for 4 Years on GH Field

Year	Crop	Acreage	Water applied ac.ft/ac./yr.	Nitrogen Fertilizer lbs - N/ac./yr.	Ave.
1962	tomatoes	122	3.1	N.A.[1]	
	cotton	80	2.3	"	
	wheat	53	0.7	"	
1963	safflower	122	0.9	none	
	safflower	80	0.8	"	
	safflower	53	0.8	"	
1964	barley	122	1.8	106	
	lettuce	80	4.9	47	92
	cotton	53	2.6	127	
1965	safflower	122	2.0	125	
	safflower	80	0.9	125	125
	safflower	53	1.1	125	

1/ not available

Table 7

Application of Water and Fertilizer for 1966 on GH Field

Crop	Acreage	Irrigation ac.ft/ac.	Irrigation Date From - to	Fertilizer lbs.-N/ac.	Fertilizer Type	Fertilizer Date
cotton	122	1.2	3/4 - 3/13	85	NH_3[1]	5/31
		0.5	6/21 - 6/29	79	NH_3	6/4
		0.4	7/20 - 7/27			
		0.5	8/3 - 8/11			
		0.3	8/13 - 8/17			
bell peppers	80	1.3	5/10 - 5/16	34	8-10-12	5/11
		0.6	6/3 - 6/7			
		0.7	6/7 - 6/15			
		0.5	6/11 - 6/16			
		0.4	7/13 - 7/17	64	15-8-0	8/1
		0.4	8/3 - 8/9			
		0.4	8/26 - 8/30			
barley & lettuce	53	0.8	4/1 - 4/5	55	urea	2/24
		0.9	6/29 - 7/11	200	manure[2]	3/11
		1.0	7/25 - 8/26		"	6/9
		0.1	8/31 - 9/2	30	10-10-10	5/11
		0.1	9/8 - 9/13	10	10-10-10	6/28
		0.3	9/15 - 9/21			

1/ Anhydrous ammonia
2/ Steer manure - approximately 2% nitrogen according to State Agricultural official.

to this property than to the DS field listed above. For the past 4 years an average of 95 pounds of Nitrogen fertilizer was added, Tables 6 and 7. Most of the chemical fertilizer, if not present in the nitrate form, will be nitrified in 2 to 3 weeks after application but the manure, Table 6, will be slower and decomposition may require a year or more for complete nitrification of the proteinaceous material.

Soil Salinity: The GH area contained 2 major fields - one planted to cotton, 122 acres, and the other to bell peppers, 80 acres. Both fields are rectangular in shape and soil samples were taken separately from each field. Opposite ends of the cotton field were designated as location GH-A and B and for the bell peppers as GH-C and D. Both of these fields, including a triangular field of 53 acres, have a common drainage outlet.

The analyses of the saturation extract for the soil profiles of the cotton field are given in Table 8. Relatively high salinity and boron occurs at all sites sampled. The principal salt is sodium sulfate which coupled with calcium concentration, indicates the presence of gypsum except in the surface soil at location A, site 1 and 3. In the surface foot of soil nitrate-nitrogen is extremely high except at site 3. This is due to the injection of 164 pounds of NH_3 on May 31 and June 4, Table 7. To prevent "burning" of the young cotton plant, the application was made some distance from the row, usually on the side or bottom of the furrow. As the first soil samples were taken before irrigation, June 21, the nitrates were very high in the surface foot and the variation in concentration is related to the proximity of the soil sample to the point of NH_3 injection.

The moisture relations, nitrogen content and salts for the 4 soil profiles are given in Table 9. The field moisture in acre inches per acre show some variations due to depth of sampling, but for a 7 foot profile the average is32 $\pm$ 1 inch for individual sites. The nitrate-nitrogen in the profile is very high because the first foot of soil was sampled in the fertilizer band. The exception is site 3 where the fertilizer band was apparently missed.

Gypsum was found at all sampling sites and at location B small amounts were found in the surface foot of soil; consequently, the overall salinity of the profiles is relatively high.

For GH-C and D locations (bell pepper field) the results of the saturation extract for the soil profiles are given in Table 10. The overall salinity

Table 8

Analyses of the Saturation Extract for Soil Profiles of GH, Location A and B, (Cotton) for 2 Sampling Dates

Depth feet	ECX10^3	Boron ppm	Milliequivalents per Liter								
			HCO_3	Cl	SO_4	NO_3	Na	Ca	Mg	K	Total
Site 1, sampled 6/21, Location A											
0-1	2.4	0.4	3.8	4.1	4.5	11.07	6.3	12.0	3.3	0.8	22.4
1-2	1.2	0.5	3.2	4.1	4.3	0.20	4.8	5.0	1.2	0.4	11.4
2-3	1.4	0.7	2.7	5.2	7.0	0.55	7.2	5.5	2.1	0.3	15.1
3-4	3.7	1.4	2.2	8.1	40.7	0.43	15.6	24.0	10.7	0.7	51.0
4-5	5.5	2.6	1.1	16.8	52.0	0.23	27.6	28.0	13.3	0.8	69.7
5-6	6.1	2.9	1.6	16.5	59.4	0.21	33.9	28.0	14.2	0.8	76.9
6-7	5.9	2.5	1.6	13.7	61.8	0.21	43.6	22.0	10.7	0.8	77.1
7-8	5.4	2.2	1.1	8.9	60.8	0.19	32.2	24.0	13.0	0.8	70.0
Site 2, sampled 6/21, Location B											
0-1	4.8	2.7	3.2	8.3	41.5	6.43	19.0	30.0	8.7	1.3	59.0
1-2	5.8	5.4	2.2	11.7	58.2	1.36	34.8	23.0	14.3	0.7	72.8
2-3	8.2	9.0	2.2	19.9	83.3	0.45	65.2	24.0	14.2	0.8	104.2
3-4	9.1	8.1	2.2	15.1	99.6	0.41	72.2	26.0	16.7	0.8	115.7
4-5	6.8	4.6	2.2	8.6	78.8	0.55	53.5	24.0	11.3	0.7	89.5
5-6	6.9	4.3	1.6	7.5	79.1	0.55	52.2	24.0	10.7	0.7	87.6
6-7	6.1	3.5	2.2	4.1	76.4	0.19	45.9	23.0	12.2	0.8	81.9
Site 3, sampled 7/20, Location A											
0-1	1.0	4.7	3.8	3.6	3.6	0.21	3.8	5.0	1.2	0.4	10.4
1-2	1.3	0.5	3.2	3.6	6.7	0.12	5.7	5.2	1.7	0.3	12.9
2-3	2.1	0.5	2.7	6.4	11.2	0.29	11.1	6.0	2.7	0.3	20.1
3-4	5.0	1.2	1.6	11.7	49.3	0.16	28.7	23.0	9.8	0.7	62.2
4-5	7.6	2.1	1.6	21.9	73.7	0.12	51.3	29.0	15.0	0.8	96.1
5-6	8.0	4.0	1.6	16.8	87.7	0.14	60.9	28.0	14.3	0.8	104.0
6-7	7.6	4.6	1.6	9.2	91.5	0.16	62.6	24.0	14.3	0.7	101.6
7-8	7.4	4.7	1.6	5.0	93.1	0.15	60.2	24.0	14.3	0.7	99.2
8-9	7.5	4.7	1.6	5.2	93.4	0.17	58.0	25.0	15.0	0.6	98.6
Site 4, sampled 7/20, Location B											
0-1	4.6	1.6	1.6	13.1	34.5	3.57	14.6	29.0	8.7	1.0	53.3
1-2	5.3	2.7	1.6	13.1	51.0	1.25	26.1	30.0	11.0	0.5	67.6
2-3	8.8	10.0	1.6	25.5	85.8	0.79	68.3	28.0	15.0	0.6	111.9
3-4	9.6	8.1	1.6	26.1	94.4	0.33	80.0	27.0	14.3	0.6	121.8
4-5	8.6	5.7	1.6	21.9	91.9	0.28	73.0	27.0	14.3	0.6	114.9
5-6	7.7	5.2	1.6	13.1	89.8	0.23	62.3	27.0	13.7	0.6	103.6
6-7	7.4	5.2	1.6	7.8	85.3	0.19	55.2	26.0	11.7	0.5	83.4
7-8	7.2	5.6	1.6	6.1	90.0	0.26	56.5	26.0	12.5	0.6	95.6

Table 9

Profile Distribution of Field Moisture, Saturation Percentage Nitrogen as Nitrates, and Salts on the Oven Dry Bases for Field GH Locations A and B

Depth Feet	Field Moisture %	Depth ac.in.	Saturation[1] %	lbs NO_3-N[2] ac.ft.	Me per 100 gr Soil Soluble Salt	Gypsum
			Site 1, sampled 6/21, Location A			
0-1	23.7	3.5	74.4	319.5	1.7	
1-2	27.6	41.	73.6	7.0	0.8	
2-3	28.9	4.3	71.5	18.8	1.1	
3-4	31.7	4.7	78.0	15.9	4.0	1.5
4-5	31.6	4.7	81.6	8.9	5.7	19.2
5-6	31.9	4.8	82.0	8.1	6.3	26.7
6-7	34.0	5.1	71.5	7.2	5.5	24.3
7-8	32.2	4.8	68.0	6.1	4.6	16.1
Total		36.0		463.5	29.7	87.8
			Site 2, sampled 6/21, Location B			
0-1	24.0	3.6	69.4	212.4	4.1	3.1
1-2	27.5	4.1	64.6	41.8	4.7	10.8
2-3	29.0	4.3	66.7	14.3	6.9	11.4
3-4	30.5	4.6	76.0	14.8	8.8	13.5
4-5	37.7	5.7	77.8	20.4	7.0	10.0
5-6	35.0	5.2	71.1	18.6	6.6	19.9
6-7	35.6	5.3	65.3	5.9	5.4	23.2
Total		32.8		328.2	43.5	91.9
			Site 3, sampled 7/20, Location A			
0-1	23.3	3.5	67.0	6.6	0.7	
1-2	25.5	3.8	68.4	3.9	0.9	
2-3	30.2	4.5	72.6	10.0	1.5	
3-4	32.3	4.8	75.4	5.7	4.7	5.8
4-5	31.5	4.7	73.4	4.2	7.0	35.5
5-6	33.1	5.0	79.3	5.3	8.3	45.0
6-7	34.2	5.1	78.9	5.9	8.0	39.6
7-8	31.0	4.6	76.1	5.4	7.5	43.6
8-9	32.3	4.8	69.5	5.6	6.8	28.6
Total		40.8		52.6	45.4	198.1
			Site 4, sampled 7/20, Location B			
0-1	22.0	3.3	67.0	113.8	3.6	4.7
1-2	23.6	4.9	63.9	52.5	4.3	7.3
2-3	30.0	4.5	71.9	27.0	8.0	29.7
3-4	32.5	4.9	84.9	13.4	10.3	33.6
4-5	35.0	5.2	79.2	10.6	9.1	47.3
5-6	31.6	4.7	74.3	8.2	7.7	37.5
6-7	33.0	4.9	77.1	7.0	7.2	31.4
7-8	32.1	4.8	72.2	8.9	6.9	27.6
Total		37.2		241.4	57.1	219.1

1/ Pore volume saturation under field conditions ± 52.8%

2/ Acre foot soil = approximately 3.4 million pounds

Table. 10

Analyses of the Saturation Extract for Soil Profiles of GH, Location C and D (Bell Peppers) for Two Sampling Dates

Depth		Boron	Milliequivalents per Liter								
Feet	ECX10^3	ppm	HCO_3	Cl	SO_4	NO_3	Na	Ca	Mg	K	Total
			Site 5, sampled 7/12, Location C								
0-1	1.1	0.4	3.8	3.6	3.1	0.48	5.2	3.7	1.5	0.4	10.8
1-2	1.0	0.2	3.2	3.3	4.1	0.11	4.0	4.5	1.5	0.3	10.3
2-3	2.1	1.0	2.7	5.8	15.1	0.29	8.4	10.0	4.3	0.3	23.0
3-4	4.7	1.9	1.6	13.4	45.3	0.33	26.1	24.0	10.3	0.6	61.0
4-5	6.5	3.8	1.6	19.3	63.5	0.15	43.5	28.0	13.7	0.6	85.7
5-6	6.8	4.1	1.6	10.9	80.3	0.11	52.6	24.0	15.0	0.5	92.1
6-7	6.2	3.2	1.6	8.1	74.9	0.12	46.5	24.0	12.5	0.6	83.5
7-8	6.9	4.4	1.6	6.7	80.2	2.41	50.0	25.0	14.3	0.5	89.8
			Site 6, sampled 7/12, Location D								
0-1	2.4	0.5	3.8	7.8	15.1	0.12	11.3	11.0	3.0	0.7	26.0
1-2	5.5	2.5	2.2	13.7	55.6	0.15	33.0	26.0	11.7	0.7	71.3
2-3	9.4	6.4	1.6	36.5	77.1	1.07	69.8	29.0	15.8	0.7	115.3
3-4	10.1	7.5	2.2	41.6	84.0	0.89	81.6	29.0	17.3	0.6	128.5
4-5	9.4	5.0	1.6	37.4	77.1	1.36	73.0	28.0	15.0	0.6	116.6
5-6	8.2	3.8	1.6	33.4	68.2	1.61	60.2	28.0	15.0	0.6	103.7
6-7	6.7	3.6	1.1	13.7	71.6	0.89	47.8	27.0	12.5	0.5	87.8
			Site 7, sampled 8/17, Location C								
0-1	1.1	0.4	3.0	4.0	4.6	0.14	5.0	4.7	1.5	0.4	11.6
1-2	1.1	0.6	2.4	2.9	4.8	0.23	5.6	3.0	1.2	0.2	10.0
2-3	3.9	1.4	1.6	6.4	42.9	0.61	19.3	23.0	9.2	0.4	51.9
3-4	5.5	2.6	1.6	13.7	52.0	0.71	30.4	26.0	11.7	0.5	68.6
4-5	6.5	4.0	1.6	15.7	65.8	0.41	44.3	24.0	14.0	0.5	82.8
5-6	5.5	3.1	1.6	10.0	62.0	0.43	32.2	27.0	14.0	0.3	73.4
6-7	5.1	2.2	1.3	9.6	55.1	0.26	25.6	26.0	14.0	0.3	65.9
7-8	4.2	1.4	1.1	11.3	44.5	0.26	16.6	29.0	11.7	0.3	57.5
			Site 8, sampled 8/17, Location D								
0-1	2.1	1.1	3.2	6.5	12.9	0.12	10.0	9.5	2.9	0.5	22.9
1-2	4.4	2.6	2.4	8.2	46.0	0.12	23.9	24.0	9.2	0.4	57.5
2-3	8.2	7.0	2.2	26.9	72.8	0.43	59.1	28.0	15.0	0.5	102.6
3-4	10.0	7.8	2.2	36.2	84.8	0.96	77.4	28.0	17.2	0.5	123.1
4-5	9.1	5.8	1.6	36.0	72.6	1.20	68.7	27.0	15.0	0.5	111.2
5-6	8.8	5.0	1.6	39.6	63.9	1.75	61.7	29.0	15.0	0.3	106.0

is similar to GH-A and B; however, the average chloride content is somewhat higher which may indicate this part of the field was drained in 1965. The fertilizer used on this field was a dry mix and probably placed in the plant bed as there is no evidence of high nitrates in the surface soil taken from the bottom of the furrow.

In Table 11 is given the pertinent information concerning soil moisture, nitrate-nitrogen, and salinity of the soil profile. The moisture characteristics are similar to the cotton area, location A and B except a lighter subsoil occurs at the 6 to 8 foot depth. The nitrate content of the profile is low at location C as compared to D. This is also in evidence for chlorides, Table 10. Either this end of the field has had more leaching or less natural accumulation of salts than the opposite end, location D.

Gypsum occurs in the subsoil at all sites sampled, Table 11; however, the four sites average somewhat less gypsum than in the cotton field, locations A and D.

Effluent composition and drain discharge. From June 21 to August 31, ten samples of the drainage waters were collected and analyzed, Table 12. The constituents in the effluent remained fairly uniform during this period; however, the total salinity was lower with an average sodium percentage of 43 and nitrates and boron less than the DS property. The 6 groundwater samples showed wide variation in nitrate content - ranging from 0.46 to 3.39 with an average of 1.70 me/L (105 ppm NO_3) which compares favorably with the effluent concentration of 1.65.

The analysis of the irrigation water, August 18, botton of Table 12, is from the same canal as serves DS but at a distance of about 3 miles. The composition of both samples is similar.

The discharge from the tile drain was periodically measured and a hydrograph plotted in Figure 2, along with the dates of irrigation and quantity of water applied. Because of diversity of crops and frequency of irrigation on this drainage field the tile discharge does not follow the number of irrigations, but peak flow occurs when irrigations are "heavy", approximately an ac/ft/ac. or more. In general the "light" irrigations replenish the water lost by evapotranspiration. Discharge measurements made during September showed a tapering off of flow to about 25 gpm by the first week of October.

Table 11

Profile Distribution of Field Moisture, Saturation Percentage, Nitrate Nitrogen, and Salts on the Oven Dry Bases for Field GH Locations C and D

Depth Feet	Field Moisture %	Depth ac.in.	Saturation[1] %	lbs NO_3-N[2] ac.ft.	Me per 100 gr Soil Soluble Salts	Gypsum
			Site 5, sampled 7/12, Location C			
0-1	35.4	5.3	73.7	16.8	0.8	
1-2	34.4	5.2	77.9	4.0	0.8	
2-3	31.5	4.7	63.2	8.7	1.5	
3-4	32.4	4.9	64.9	10.2	4.0	2.5
4-5	31.2	4.7	73.0	5.2	6.3	14.5
5-6	30.4	4.6	78.0	4.0	7.2	27.8
6-7	30.7	4.6	71.2	4.1	5.9	25.9
7-8	32.3	4.8	57.3	65.7	5.1	21.4
Total		38.8		118.7	31.6	92.1
			Site 6, sampled 7/12, Location D			
0-1	33.4	5.0	78.9	4.4	2.0	
1-2	33.7	5.0	79.3	5.6	5.7	4.6
2-3	33.7	5.0	82.9	42.2	9.5	34.6
3-4	31.2	4.7	85.6	36.3	11.0	34.9
4-5	31.2	4.7	73.3	47.4	8.5	27.5
5-6	33.1	5.0	71.2	54.6	7.4	30.2
6-7	33.6	5.0	54.9	23.3	4.8	23.0
Total		34.4		213.8	48.9	154.8
			Site 7, sampled 8/17, Location C			
0-1	34.6	5.2	83.3	5.5	1.0	
1-2	33.2	5.0	81.6	8.9	0.8	
2-3	34.0	5.1	79.2	23.0	4.1	6.7
3-4	38.1	5.7	77.4	26.2	5.3	15.7
4-5	33.4	5.0	81.8	15.9	6.8	28.4
5-6	31.0	4.6	70.9	14.5	5.2	21.3
6-7	31.2	4.7	63.6	7.8	4.2	21.2
7-8	29.5	4.4	56.2	6.9	3.2	8.3
Total		39.7		108.7	30.6	101.6
			Site 8, sampled 8/17, Location D			
0-1	32.0	4.8	76.8	4.3	1.8	
1-2	31.2	4.7	76.8	4.3	4.4	1.9
2-3	32.2	4.8	75.1	15.4	7.7	19.9
3-4	32.2	4.8	80.3	36.7	9.9	37.7
4-5	31.3	4.7	77.4	47.1	8.6	32.1
5-6	32.1	4.8	66.7	55.5	7.1	30.8
Total		28.6		163.3	39.5	122.4

1/ Pore volume saturation under field conditions ± 52.8%

2/ Acre foot soil = approximately 3.4 million pounds

Table 12

Analyses of the Drainage Effluent for Various Dates, Ground and Irrigation Water for CH Field

Date 1966	ECX10^3	Boron ppm	Milliequivalents per Liter								
			HCO_3	Cl	SO_4	NO_3 as N	Na	Ca	Mg	K	Total Cations
Drainage Water											
6/21	5.2	5.3	5.9	13.4	49.8	1.07	27.6	28.0	13.3	0.4	69.3
7/1	6.1	7.3	5.9	19.6	56.7	1.64	39.1	27.0	15.8	0.8	82.7
7/7*	6.4	7.7	4.4	18.4	52.9	1.74	24.0	28.8	13.8	0.2	66.8
7/12	6.0	6.8	5.9	18.5	55.6	1.86	39.1	27.0	14.2	0.7	81.0
7/18	5.4	5.2	4.8	13.4	47.4	1.28	26.6	25.0	13.8	0.2	65.6
7/25	5.4	5.8	4.8	14.5	50.6	1.43	29.2	26.0	14.3	0.2	69.7
8/2	7.3	7.6	4.8	26.4	53.9	2.57	43.5	29.0	15.8	0.4	88.7
8/10*	5.6		4.4	14.3		1.77	29.8	27.6			
8/18	7.1	7.1	5.4	26.7	52.9	1.68	39.1	29.0	16.7	0.4	85.2
8/31	5.5	6.0	4.8	15.1	48.2	1.36	28.7	27.0	14.5	0.3	70.5
Ave.	6.0	6.5	5.1	18.0	52.0	1.64	32.7	27.4	14.7	0.4	75.2
Ground Water											
A-7/20*	7.5					1.21					
B-7/20*	8.8					1.22					
C-7/12	7.8					0.46					
C-8/17	4.9	3.5	5.9	19.6	41.0	0.62	17.6	33.0	15.8	0.4	66.8
D-7/12	9.3					3.39					
D-8/17	12.0	11.8	5.9	75.7	6.28	3.32	82.6	39.0	24.7	0.4	146.7
Irrigation Water											
8/18		0.72	1.7	3.7	1.5	0.15	3.9	1.4	1.7	0.1	7.1

*Analyzed by Department of Water Resources.

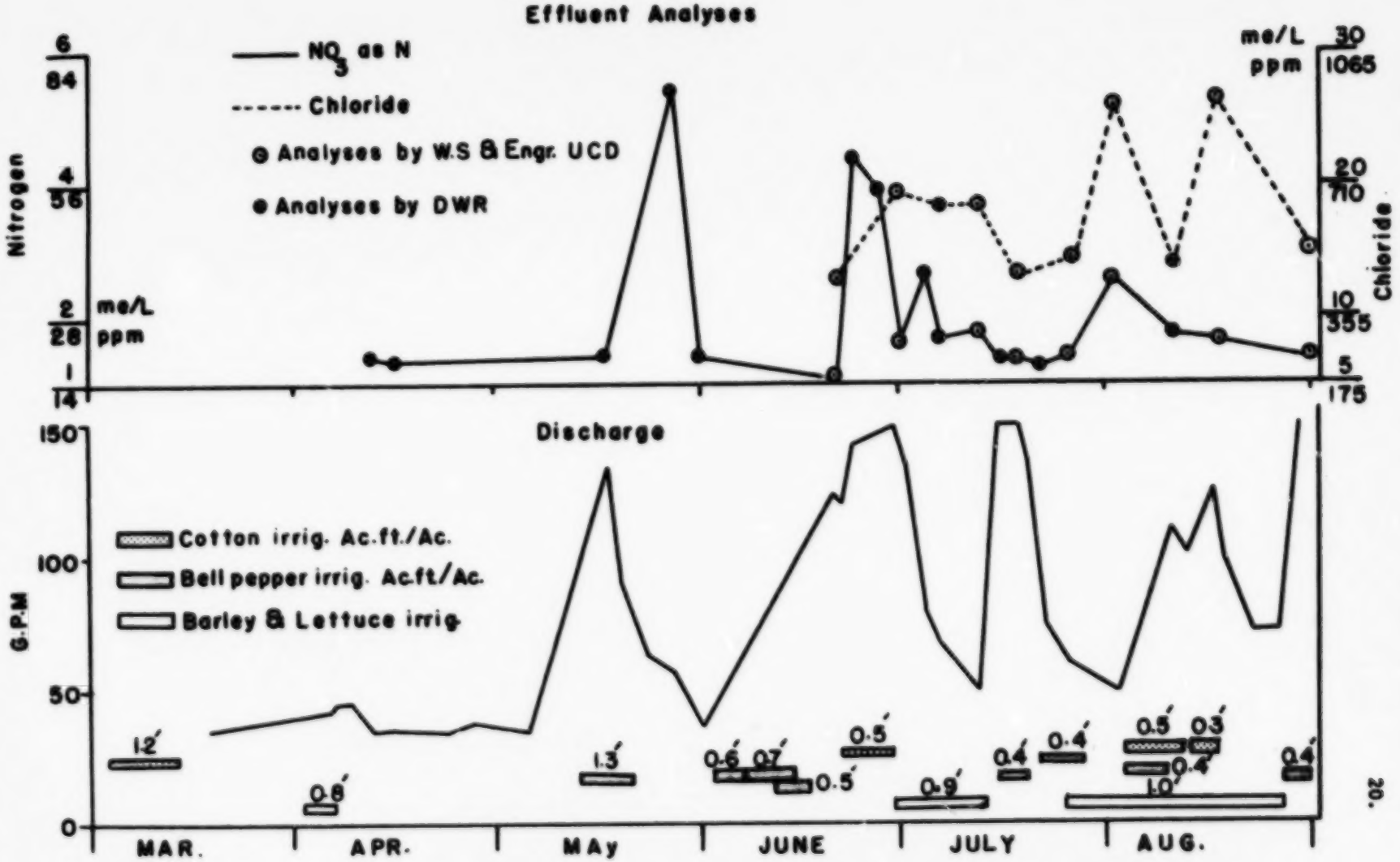

FIG. 2. Hydrograph of Discharge and Nitrate-Chloride Concentration of Effluent for GH Field.

In general there is no correlation in the concentration of soluble ions (chlorides and nitrates) with tile discharge and variations that did occur appear to be independent of flow.

GT-Drain Field

This is a small triangular field of 17 acres. The tile drain was installed in September of 1965 at a depth of 7.2 feet with spacing between lateral drains of 150 feet.

Farm management: Table 13 gives the crop grown, fertilizer and water applied to the area from 1962 to 1965 and Table 14 for the year 1966. Three irrigations of 2.1 ac. ft/ac. were applied to cotton this year and a 4 year average of 105 pounds of nitrogen fertilizer.

Table 13

Historical Management for 4 Years on GT Field

Year	Crop	Acreage	Water Applied ac.ft/ac./yr	Nitrogen Fertilizer lbs.-N ac./yr.
1962	safflower	17	1.3	N.A.*
1963	safflower	17	0.6	none
1964	cotton	17	3.3	131
1965	safflower	17	1.3	125

* NA - not available

Table 14

Application of Water and Fertilizer for 1966 on GT Field

Crop	Acreage	Irrigation ac./ft/ac.	Irrigation Date from - to	Fertilizer lbs.-N/ac.	Fertilizer Type	Fertilizer Date
cotton	17	0.7	3/14 - 3/16	91	NH_3 1/	5/16
		0.6	6/22 - 7/5	75	NH_3 1/	6/7
		0.8	7/23 - 8/17			

1/ anhydrous ammonia

Soil salinity: The triangular field was sampled at two locations at opposite ends of the hypotenuse. The analyses of the saturation extract for the profiles are given in Table 15. The average salinity in the profiles is 87 and 167 percent greater than in GK and DS fields respectively. The increase has been in chloride, sulfate, and sodium ions.

Table 15

Analyses of the Saturation Extract for Soil Profiles of GT Location A and B for 2 Sampling Dates

Depth Feet	ECX10[a]	Boron ppm	Milliequivalents per Liter								
			HCO_3	Cl	SO_4	NO_3	Na	Ca	Mg	K	Total
Site 1, sampled 6/21, Location A											
0-1	2.7	0.8	4.3	5.8	12.7	4.18	11.3	11.0	3.2	0.9	26.4
1-2	7.7	5.8	2.7	21.6	70.9	0.68	53.9	28.0	11.7	0.7	94.3
2-3	13.0	11.8	2.2	55.4	103.7	2.14	110.9	30.0	20.0	0.8	161.7
3-4	15.3	13.6	1.6	66.7	122.8	2.14	147.8	25.0	20.0	0.9	193.7
4-5	13.3	10.6	1.6	52.9	119.5	1.39	123.9	28.0	21.3	0.8	174.0
5-6	11.0	6.9	1.6	32.9	102.7	0.78	92.6	25.0	18.7	0.7	137.0
6-7	8.8	4.9	2.2	23.6	84.8	0.86	63.0	28.0	18.3	0.8	110.1
Site 2, sampled 6/21, Location B											
0-1	3.5	1.6	3.2	12.0	13.3	8.21	15.6	16.0	3.3	0.7	35.6
1-2	6.9	5.4	2.7	23.8	63.2	0.24	45.9	30.0	12.2	0.7	88.8
2-3	12.0	10.6	1.6	48.1	97.7	0.57	103.5	27.0	15.8	0.8	147.1
3-4	13.4	12.0	1.6	50.9	112.6	0.48	115.2	28.0	20.0	0.8	164.0
4-5	15.9	12.4	2.2	72.0	117.8	0.50	132.2	29.0	29.0	0.7	190.9
5-6	15.4	11.0	2.2	70.0	128.4	0.54	138.3	28.0	32.5	0.7	199.5
6-7	15.4	11.4	1.6	67.8	136.0	0.89	144.3	27.0	32.5	0.8	204.6
Site 3, sampled 8/18, Location A											
0-1	5.9	0.4	2.2	9.8	63.5	0.34	42.6	24.0	8.0	0.8	75.4
1-2	8.0	5.3	2.7	23.3	76.6	0.13	62.6	26.0	11.7	1.0	101.3
2-3	12.7	8.5	1.6	50.9	104.6	1.07	115.2	26.0	12.5	1.0	154.7
3-4	14.2	11.2	2.2	62.1	118.1	1.14	141.5	25.0	14.7	1.0	182.2
4-5	13.8	12.4	2.2	44.4	127.4	0.73	138.0	23.0	13.3	0.8	175.1
5-6	12.1	9.8	1.6	30.3	126.2	0.70	117.8	23.0	13.3	0.8	154.9
6-7	14.2	11.4	2.2	40.5	142.0	1.46	138.0	24.0	21.0	0.8	183.8
Site 4, sampled 8/18, Location B											
0-1	1.3	1.0	4.0	3.7	5.7	0.16	6.5	4.7	1.7	0.4	13.3
1-2	3.7	3.3	2.7	6.0	36.6	0.12	24.8	15.0	4.8	0.3	44.9
2-3	8.5	8.8	2.2	17.1	94.1	0.52	77.6	21.0	11.7	0.8	111.1
3-4	12.1	13.0	2.2	41.9	118.6	0.77	112.0	27.0	22.0	0.8	161.8
4-5	11.6	10.6	1.6	49.2	97.9	0.78	100.0	28.0	22.0	0.8	150.8
5-6	12.1	9.5	1.6	49.2	112.1	0.86	108.7	28.0	23.3	1.0	161.0
6-7	14.2	11.4	1.6	73.1	123.8	1.14	134.8	31.0	31.3	1.0	198.1

The other ions, because of limited solubility and the presence of gypsum, have remained at about the same concentration as in the other fields. This being the first year of drainage and a minimal amount of water applied for cotton, Table 14, probably little leaching of the soil occurred. Also, boron has a tendency to be higher in concentration than for the other two fields.

Previous to the first sampling, June 21, two fertilizer applications were made to the field without an intervening irrigation; consequently, the first foot of soil is extremely high in nitrate nitrogen, at sites 1 and 2. For the second soil sampling, following 2 irrigations, the nitrogen content was relatively low in the surface foot of soil, sites 3 and 4; it has either been used by the plant or distributed through the soil by leaching or subbing.

The moisture, nitrogen, and salt content of the soil profiles are listed in Table 16. The average moisture content in the 4 soil profiles average 30 ac. in/ac. and is approximately the same as the other 2 fields. The nitrogen content at the first sampling date is high because of sampling in, or near, the fertilizer band and is similar to sites 1 and 2 in the GH field.

The soluble salts in the profiles are 66 and 154 percent greater than in GH and DS fields and the difference represents the length of time the drainage system has been installed and the amount of leaching during this period. The quantity of gypsum is similar to that found in GH field.

Effluent composition and drain discharge. The effluent was periodically unmeasured from March 14 to August 30, and 11 samples were collected and analyzed between June and August 31, Table 17. The salinity is uniformly high with an average $EC \times 10^3$ of 11.5 or 150 me/L total salt, also boron is in extremely high concentration, averaging 18.6 ppm.

Although the 2 groundwater samples show wide variation in concentration and for individual ions, they are much higher than the drainage effluent from the area, Table 17.

The discharge from the tile drain is illustrated by the hydrograph in Figure 3. Also shown is the amount of irrigation water and time of application. Only two irrigations had a temporary influence on drainage flow - the pre-plant irrigation in March, and at the end of June while the cotton plants were small. These irrigations had no apparent influence on the concentration of soluble chlorides or nitrates, Figure 3.

Table 16

Profile Distribution of Field Moisture, Saturation Percentage, Nitrate Nitrogen and Salts on Oven Dry Bases for Field GT Locations A and B

Depth Feet	Field Moisture %	Depth ac.in.	Saturation[1] %	lbs NO_3-N[2] ac.ft.	Me per 100 gr Soil Soluble Salts	Gypsum
			Site 1, sampled 6/21, Location A			
0-1	18.2	2.7	63.9	126.6	1.7	
1-2	24.7	3.7	70.8	22.9	6.7	11.1
2-3	30.5	4.6	73.9	75.3	11.9	15.7
3-4	31.0	4.6	72.2	73.6	14.0	23.5
4-5	32.8	4.9	78.2	51.7	13.6	19.1
5-6	29.5	4.4	72.5	27.0	9.9	21.3
6-7	28.9	4.3	62.8	25.6	8.2	11.9
Total		29.2		402.7	66.0	102.6
			Site 2, sampled 6/21, Location B			
0-1	24.7	3.7	74.4	291.9	2.2	
1-2	29.0	4.3	76.1	8.7	6.7	7.4
2-3	32.4	4.9	78.0	21.1	11.5	16.6
3-4	39.2	5.9	71.5	16.3	11.7	13.8
4-5	31.2	4.7	59.4	13.5	11.3	11.3
5-6	32.2	4.8	56.7	14.6	11.3	10.7
6-7	35.4	5.3	56.4	23.8	13.7	11.0
Total		33.6		389.9	68.4	70.8
			Site 3, sampled 8/18, Location A			
0-1	16.1	2.4	71.2	11.5	5.4	4.9
1-2	21.7	3.2	70.8	4.4	8.5	14.0
2-3	26.1	3.9	76.7	39.0	11.8	23.6
3-4	35.3	5.3	89.1	48.4	16.3	17.9
4-5	29.8	4.5	89.1	31.0	15.6	22.8
5-6	26.4	4.0	82.9	27.6	12.8	20.7
6-7	23.6	3.5	67.7	45.4	12.4	22.4
Total		26.8		207.3	82.8	126.3
			Site 4, sampled 8/18, Location B			
0-1	20.9	3.1	67.7	5.1	0.9	
1-2	23.5	3.5	72.3	4.1	3.2	0.9
2-3	32.0	4.8	72.6	17.9	8.1	18.4
3-4	31.7	4.7	68.1	24.9	11.0	23.5
4-5	31.2	4.7	58.4	21.6	8.8	21.2
5-6	32.8	4.9	58.6	24.0	9.4	20.3
6-7	35.1	5.3	56.4	30.5	11.2	15.6
Total		31.0		128.1	52.6	99.9

1/ Pore volume saturation under field conditions ± 52.8%

2/ Acre foot soil = approximately 3.4 million pounds

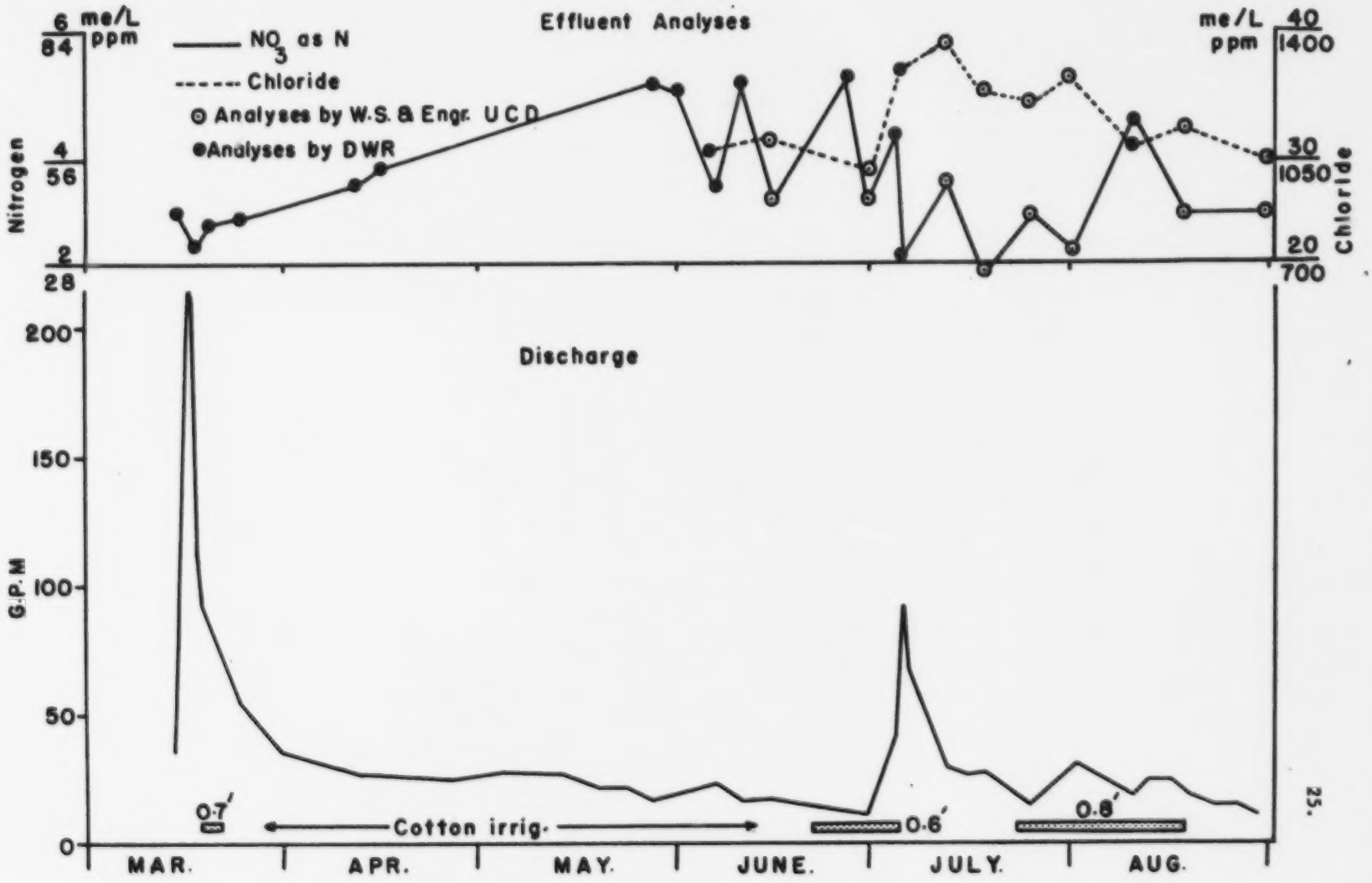

FIG. 3. Hydrograph of Discharge and Nitrate-Chloride Concentration of Effluent for GT Field.

Table 17

Analyses of the Drainage Effluent for Various Dates and the Ground Water for GT Field

Date 1966	ECX10^3	Boron ppm	Milliequivalents per Liter								
			HCO_3	Cl	SO_4	NO_3 as N	Na	Ca	Mg	K	Total Cations
Drainage water											
6/6*	11.1	20.0	4.0	28.5	106.4	3.18	92.7	24.6	24.7	0.2	142.2
6/15	11.6	18.0	4.7	31.4	111.1	2.93	95.7	26.0	26.7	0.7	149.1
6/30	11.1	16.4	5.9	28.6	108.9	2.93	95.6	21.0	27.8	0.8	145.2
7/6*	12.1	20.0	4.8	35.0	113.7	2.08	99.2	25.8	26.8	0.3	152.1
7/12	11.6	20.0	5.9	37.1	119.2	3.29	109.6	23.0	31.1	0.8	164.5
7/18	11.7	17.6	4.3	33.4	114.5	1.75	107.0	20.0	25.0	0.5	152.5
7/25	11.8	18.0	4.3	32.3	115.4	2.79	110.9	20.0	23.3	0.5	154.7
8/2	11.6	19.5	5.4	34.3	112.8	2.21	98.3	24.0	30.0	0.4	152.7
8/10*	11.4		4.0	31.6			95.7	25.1			
8/18	11.7	19.2	4.8	31.2	109.4	2.78	94.8	24.0	27.2	0.4	146.4
8/31	11.1	17.3	3.8	28.3	103.0	2.78	85.2	23.0	27.7	0.4	136.3
Ave.	11.5	18.6	4.7	32.0	111.4	2.67	99.5	23.3	27.0	0.5	150.3
Ground water											
2A-8/18	22.4	31.8	7.5	129.5	165.2	2.14	217.4	29.0	58.0	0.7	305.1
2B-8/18	15.5	26.2	3.8	46.4	150.4	4.39	160.9	21.0	20.1	0.5	202.5

* Analyses by Department of Water Resources

The GT field is a good example of the salinity accumulating in areas of high water tables as illustrated by the high salinity of the effluent, Table 17, and the saturation extract, Table 15, and the necessity of draining and leaching the soil of soluble salts to maintain economical production of even the most salt tolerant crops.

Non-irrigated, virgin areas

Soil salinity: The analyses of the saturation extract for the soil profile for the two non-irrigated areas are presented in Table 18. The salinity at GH-Vi is lower than at the PG location; however, this is reversed for nitrate content. The salt distribution in the profile for

Table 18

Analyses of the Saturated Extract for Two Soil Profiles from Non-irrigated Virgin Areas, GH-Vi and PG

Depth Feet	ECX10^3	Boron ppm	Milliequivalents per Liter								
			HCO_3	Cl	SO_4	NO_3	Na	Ca	Mg	K	Total
Location GH-Vi, sampled 7/12											
0-1	3.9	0.9	3.2	11.2	34.3	1.93	8.7	30.0	10.3	1.3	50.3
1-2	3.4	1.2	2.7	9.8	23.0	2.11	8.1	20.0	9.2	0.9	38.2
2-3	3.4	1.3	2.2	10.9	24.0	2.43	14.7	16.0	9.2	0.7	40.6
3-4	5.3	2.6	2.2	12.3	48.9	1.79	23.0	27.0	14.3	0.8	65.1
4-5	5.7	2.7	2.2	14.0	56.3	1.36	30.4	28.0	13.7	0.8	72.9
5-6	6.8	3.4	1.6	14.5	69.0	1.07	42.1	28.0	14.3	0.8	85.2
6-7	7.4	4.6	1.6	15.1	75.5	0.89	48.9	28.0	15.0	0.8	92.7
7-8	8.5	5.3	1.6	16.2	86.2	2.14	62.6	27.0	15.0	0.8	105.4
ground water											
	11.8					6.14					
Location PG, sampled 8/17											
0-1	8.2	4.3	3.2	65.0	22.8	0.12	44.3	34.0	10.5	1.3	90.1
1-2	11.3	8.2	2.2	77.1	49.6	0.14	73.1	39.0	14.7	1.3	128.1
2-3	9.4	8.8	2.7	50.9	60.8	0.14	71.7	29.0	11.7	1.0	113.4
3-4	8.5	5.3	2.2	27.5	73.1	0.11	61.7	27.0	11.7	0.8	101.2
4-5	8.0	4.3	2.2	24.7	74.5	0.11	60.9	28.0	11.7	0.8	101.4
5-6	7.5	4.1	1.6	24.7	69.7	0.11	56.5	29.0	10.5	0.5	96.5
6-7	6.1	3.5	2.2	19.9	57.5	0.15	42.6	28.0	7.5	0.3	78.4

PG would be considered typical for a moderately high water table and low rainfall area. Due to capillary movement and surface evaporation, the highest salt concentrations usually occur in the surface layers. The winter rainfall is sufficient to leach some of this salt back into the second foot where, in fact, the largest amount is found, particularly chlorides and precipitated gypsum, Table 19. In contrast the profile distribution of salts at the GH-Vi location has the appearance, to some degree, of an irrigated soil where the salt concentration increases with depth with large amounts of gypsum in the subsoil, Table 19.

Table 19

Profile Distribution of Field Moisture, Saturation Percentage, Nitrate Nitrogen and Salts on Oven Dry Bases for Non-irrigated Locations GH-Vi and PG

Depth Feet	Field Moisture %	Depth ac.in.	Saturation %	lbs-N as NO_3 ac.ft.	Me per 100 gr Soil Soluble Salts	Gypsum
			Location GH-Vi, sampled 7/12			
0-1	22.5	3.4	78.9	72.4	4.0	1.4
1-2	27.5	4.1	67.7	68.1	2.6	0.7
2-3	26.8	4.0	64.2	74.2	2.6	0.5
3-4	34.1	5.1	73.3	62.5	4.8	2.6
4-5	33.0	4.9	75.7	49.0	5.5	8.5
5-6	32.1	4.8	75.0	38.2	6.4	20.2
6-7	34.9	5.2	72.9	37.1	6.7	31.5
7-8	34.9	5.2	70.0	71.3	7.4	42.1
Total		36.7		472.8	39.0	107.5
			Location PG, sampled 8/17			
0-1	12.2	1.8	65.6	3.7	5.9	1.2
1-2	14.2	2.1	59.8	4.0	7.1	3.0
2-3	14.1	2.1	49.0	3.3	5.6	0.9
3-4	16.9	2.5	47.3	2.5	4.8	1.3
4-5	21.6	3.2	44.0	2.3	4.5	2.7
5-6	21.8	3.3	43.7	2.3	4.2	1.8
6-7	24.3	3.6	45.9	3.3	3.6	1.4
Total		18.6		18.6	35.7	12.3

Nitrates are high in the GH Vi profile and also high in the ground-water while at the PG location they are relatively low. High nitrates at 4 different locations in this area are reported by Dyer (6) for non-irrigated soils in the absence of a high water table. Although location PG is low in nitrates apparently it is not uncommon to find extremely high concentrations in the natural soil and the shallow ground water.

The soil moisture relations, nitrate nitrogen and salt content of the non-irrigated profiles are given in Table 19. From the field moisture and saturation percentage data, it is evident that the PG location is lighter soil than the other locations in this study. For the 7 foot depth the field moisture is 18.6 acre inches in depth for the PG location whereas at GH-Vi it is 31.5 or similar to the other locations. The soluble salts for the 2 locations are nearly the same but the gypsum content in the profile is higher at the GH-Vi location than at PG.

DISCUSSION

Soil moisture relations and leaching of salt. In the 3 drain fields studied the field moisture content is about 30-34 ac. in/ac. for a 7 foot depth of soil, Tables 4, 9, 11 and 16. Assuming piston displacement it would require this quantity of water for one displacement of the soil solution. However, one displacement of the soil solution does not mean that all the salts in solution will be removed from the soil profile. Laboratory and field experiments (6, 7) show considerable mixing at the interface of the leaching water and the soil solution. Under field conditions with intermittent irrigations and removal of water by plants and evaporation in the surface depths, some salt moves upward by capillarity into the drier soils; consequently, considerable mixing in the leaching profile occurs along with increased concentration of the salts from the irrigation water. In addition the Panoche loams and clay soils tend to form large cracks, often times a half inch or more across and 12 to 18 inches or more in depth as the soil dries. consequently, upon irrigation the first water reaching the soil fills these cracks, then as the mass of surface soil becomes wet and swells, the cracks are closed and the permeability rate is greatly reduced, however, this results in a considerable mixing of the irrigation water with the soil solution. In general, irrigation can be considered a leaching process in the surface soil with a deposition of salts in the subsoil, or drainage

effluent, as illustrated in Figure 9 where the surface soil is rather low in soluble salts but increasing in concentration in the subsoil with the lower 3-4 feet being fairly constant.

The soluble salts and gypsum for the individual sampling locations in tons per acre foot from the three drainage fields are presented in Figures 4, 5, 6 and 7, and for the nonirrigated locations in Figure 8. The soluble salts are only a small portion of the total potential salinity from gypsum. The exception is DS, site 1 and the small amount is derived from gypsum at site 4. A large part of the soluble salinity is derived from gypsum, which is manifested by the high sulfate content -ranging up to and over 100 me/L - in the saturation extract and drainage water, whereas the sulfate content of the irrigation water is low - 1.5 me/L. The solubility of gypsum is about 30 me/L, but the Ca so derived will replace Na and Mg on the exchange complex, which are highly soluble as SO_4 salts; consequently the salinity of the soil solution increases. The replacement power of Ca and Mg are about equal, but Ca has approximately twice the replacement power of Na on the exchange complex; therefore, the soil solutions are high in Na as illustrated by the saturation extract and drainage effluents. The common ion SO_4 depresses the solubility of gypsum as manifested in the average concentration of the effluent -ranging from about 22 to 27 me/L Ca. So long as an appreciable quantity of gypsum is in the subsoil, salinity of the drainage water will be high (5).

The average total concentration of the soluble salts and boron in the saturation extract for all sites in the three drain fields and in the effluent is presented in Figure 9. The electrical conductivity ($EC \times 10^3$) of the saturation extract is the accepted method for determination of the soil salinity and crop response (3). This widely used salinity scale is given in Table 20. The DS field - drained for about 8 years - has the lowest salt level with about 80 meq/L in the subsoil, but still in Class 3, where yields of many crops will be restricted. The more recently drained fields GH and GT have higher salinity with about 90 and 150 meq/L respectively. Only very tolerant crops can be grown satisfactorily.

Boron in irrigation water is usually rated from 0.5 ppm for sensitive crops to 2.0 ppm for tolerant species. But due to accumulation in the soil and difficulty in leaching (as it is partly fixed in the soil) the range of boron given in Table 21 may be used as a guide for sensitive plants to the very tolerant species.

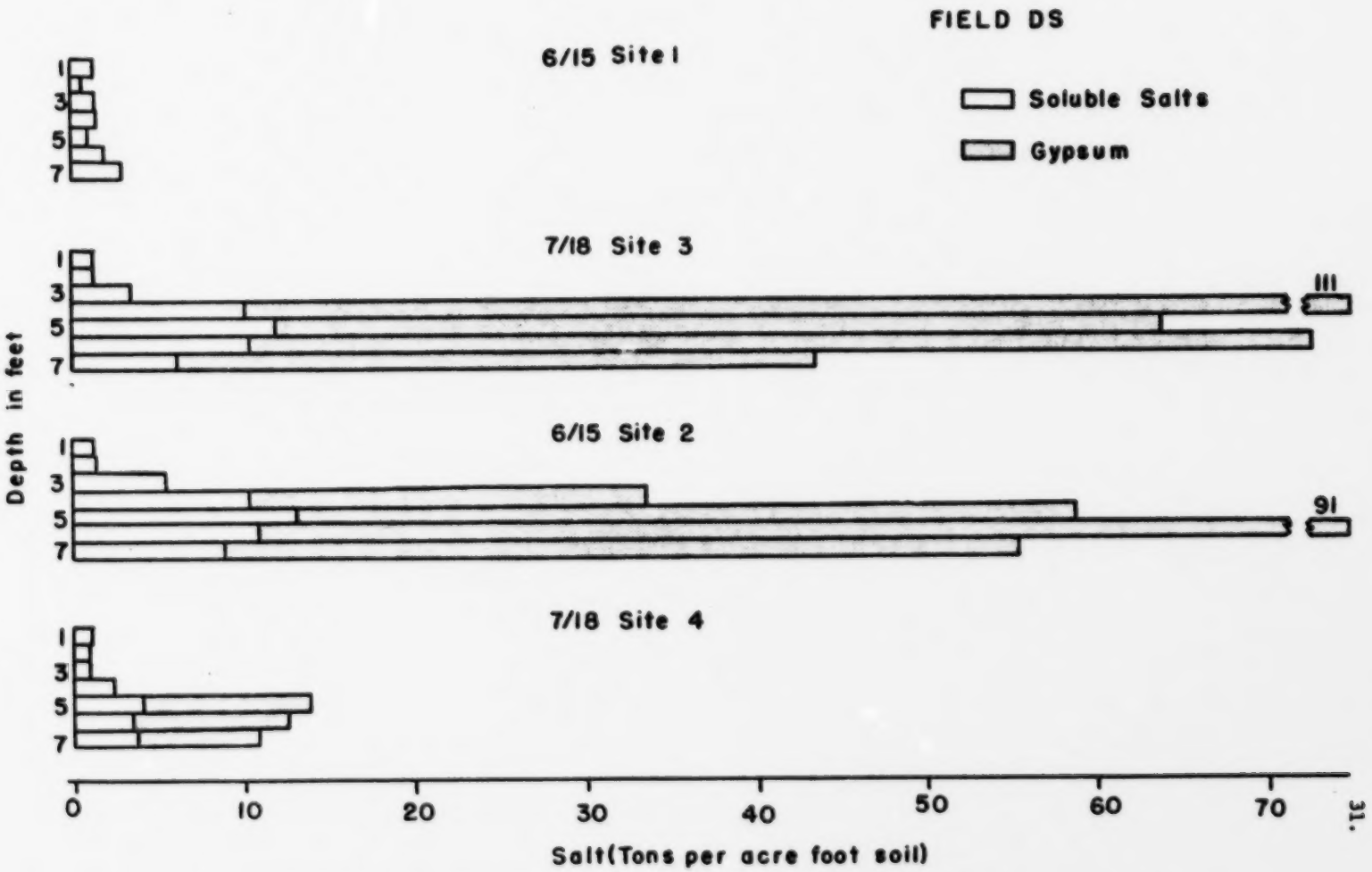

FIG. 4. Distribution of Potential Salinity (Soluble Salts and Gypsum) in Tons per Acre Foot for Soil Profiles from 2 Locations and 2 Sampling Dates for Field DS.

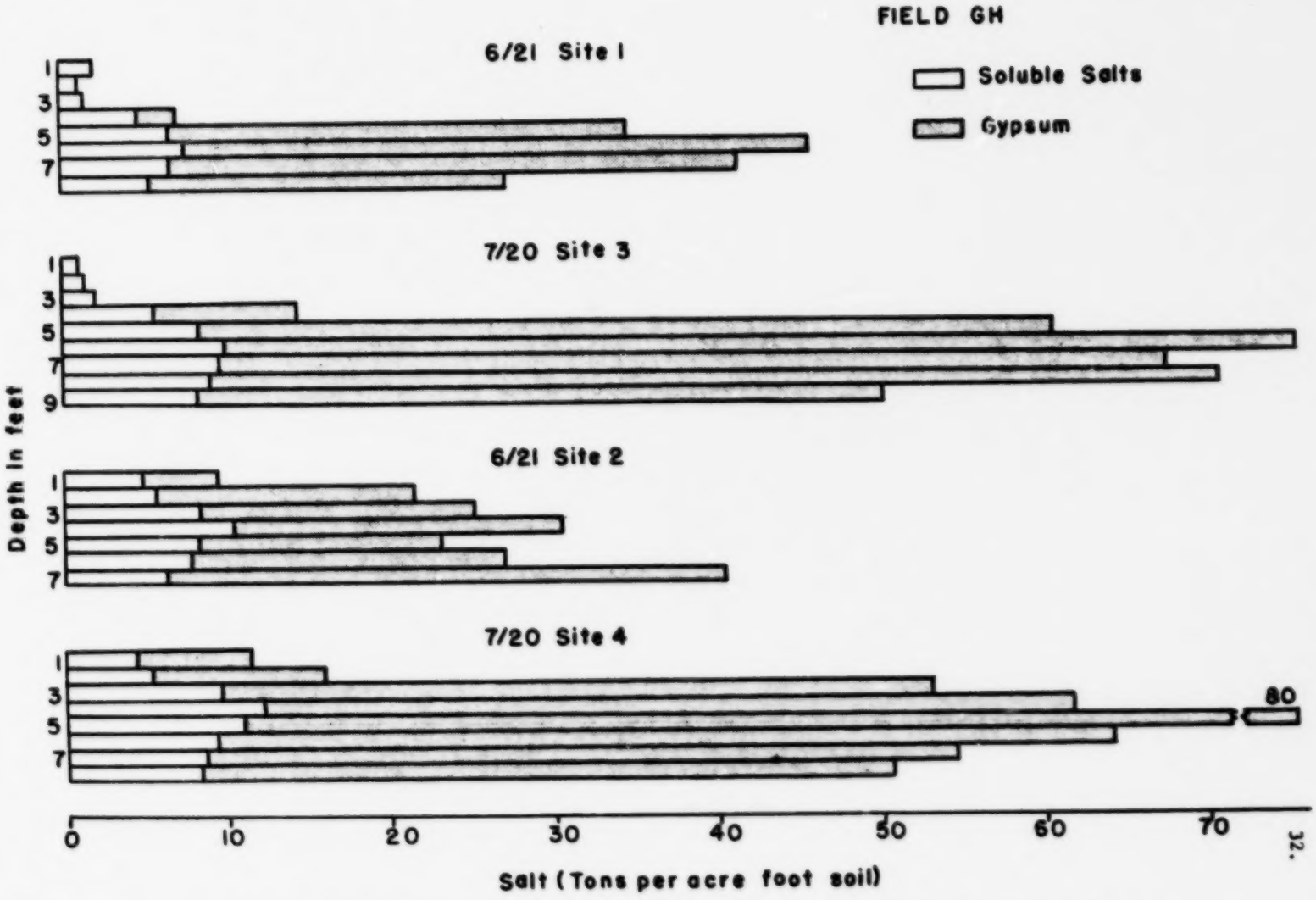

FIG. 5. Distribution of Potential Salinity (Soluble Salts and Gypsum) in Tons per Acre Foot for Soil Profiles from 2 Locations and 2 Sampling Dates for Field GH.

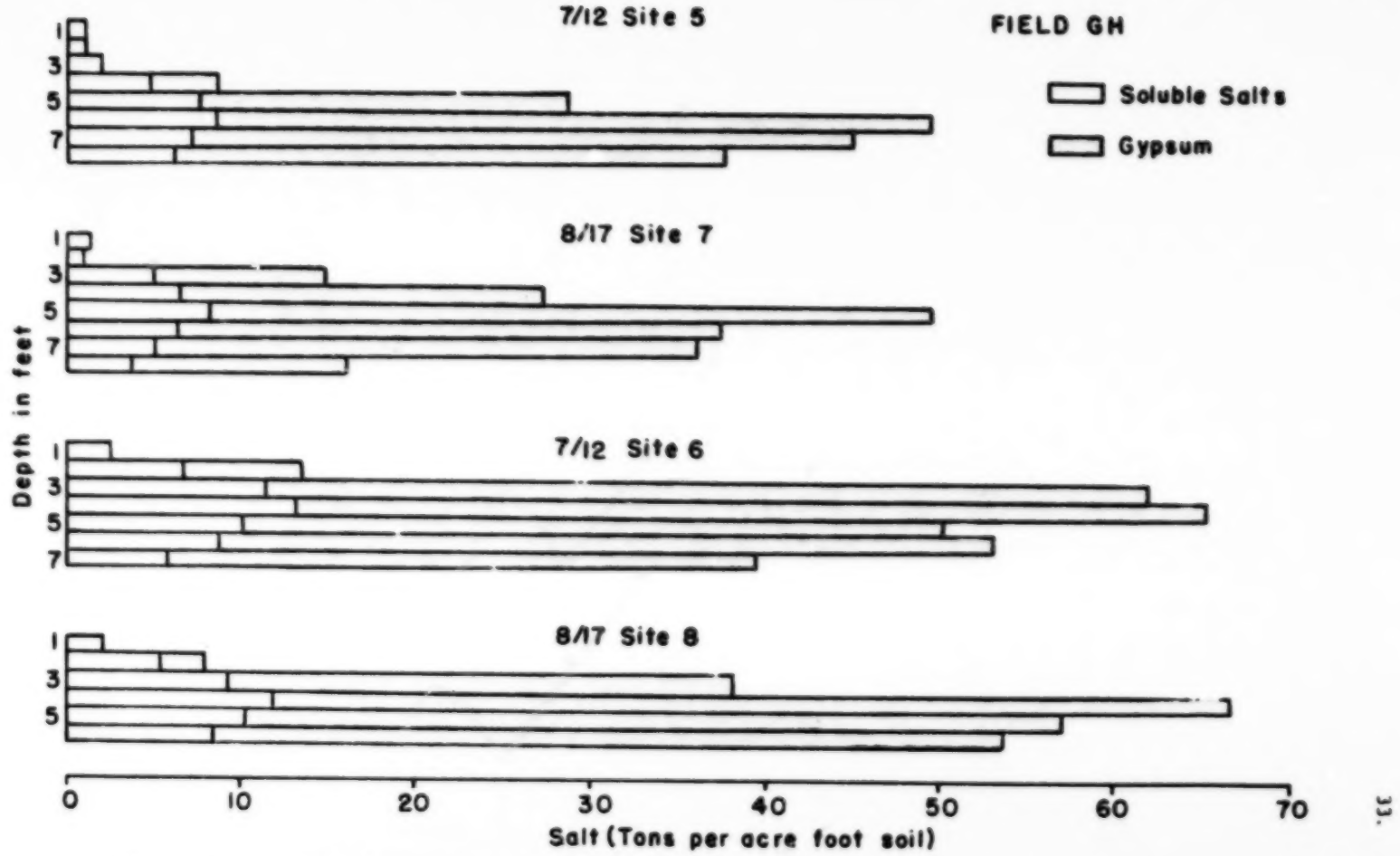

Fig. . Distribution of Potential Salinity (Soluble Salts and Gypsum) in Tons per Acre Foot for Soil Profiles from 2 Locations and 2 Sampling Dates for Field GH.

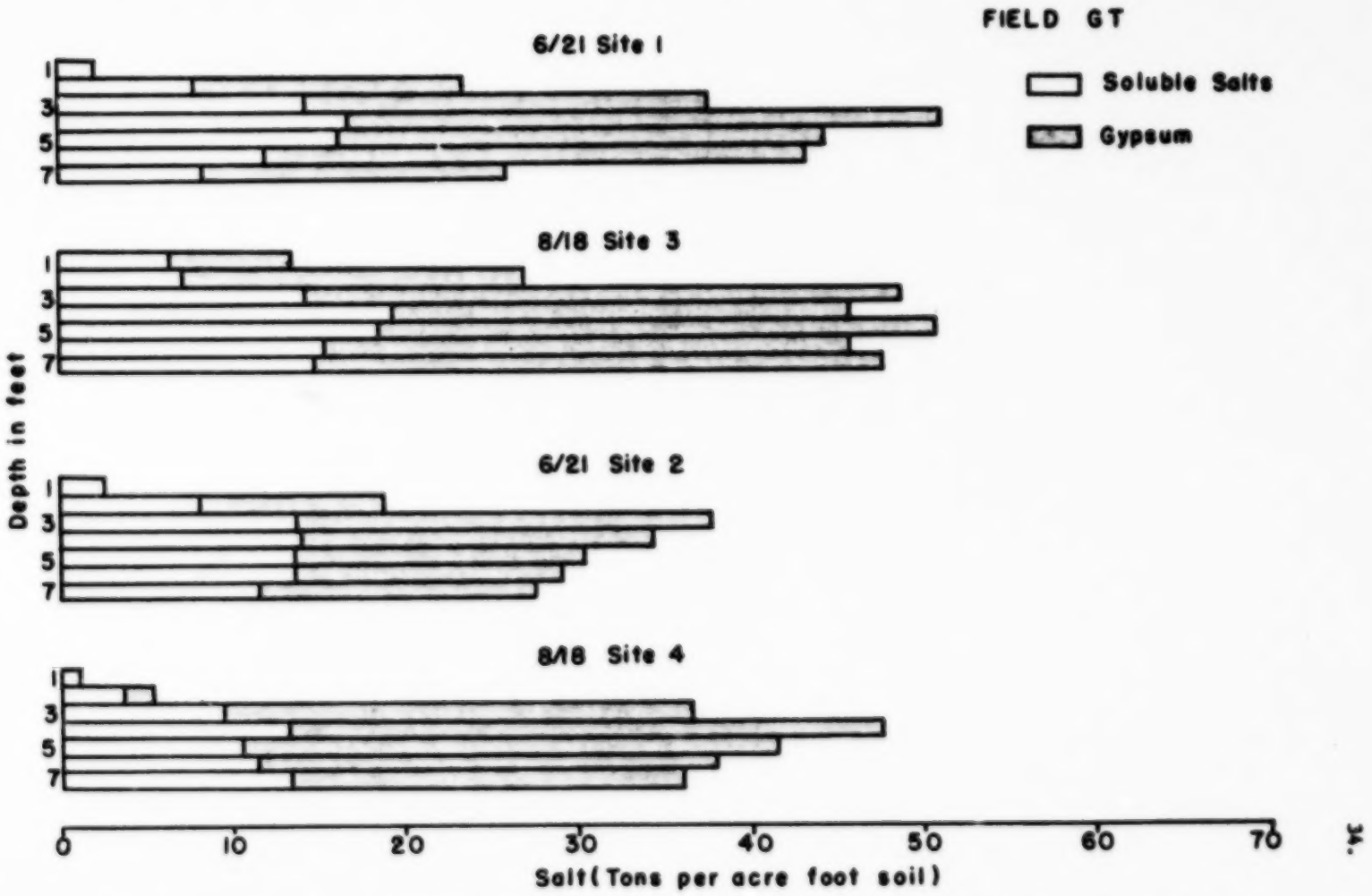

FIG. 7. Distribution of potential salinity (soluble salts and gypsum) in tons per acre-foot for soil profiles from 2 locations and 2 sampling dates for field GT.

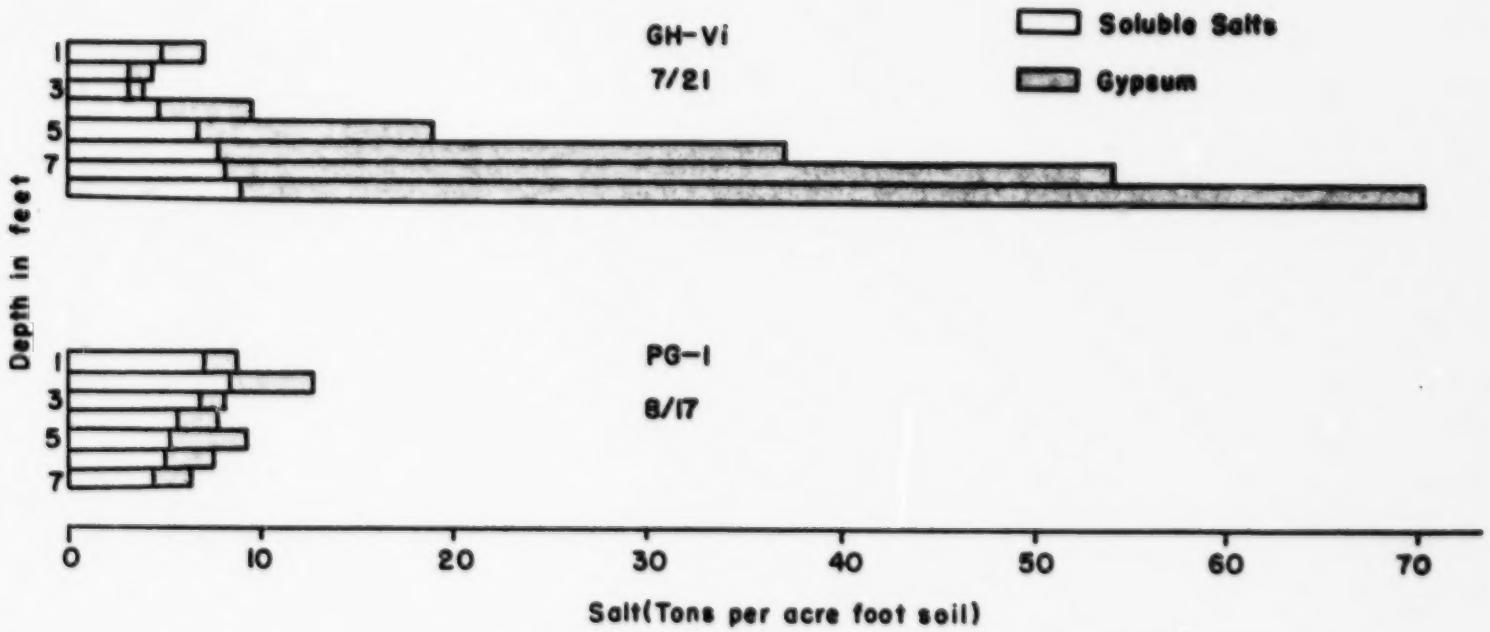

FIG. 8. Distribution of potential salinity (soluble salts and gypsum) in tons per acre-foot for soil profiles from 2 non-irrigated areas.

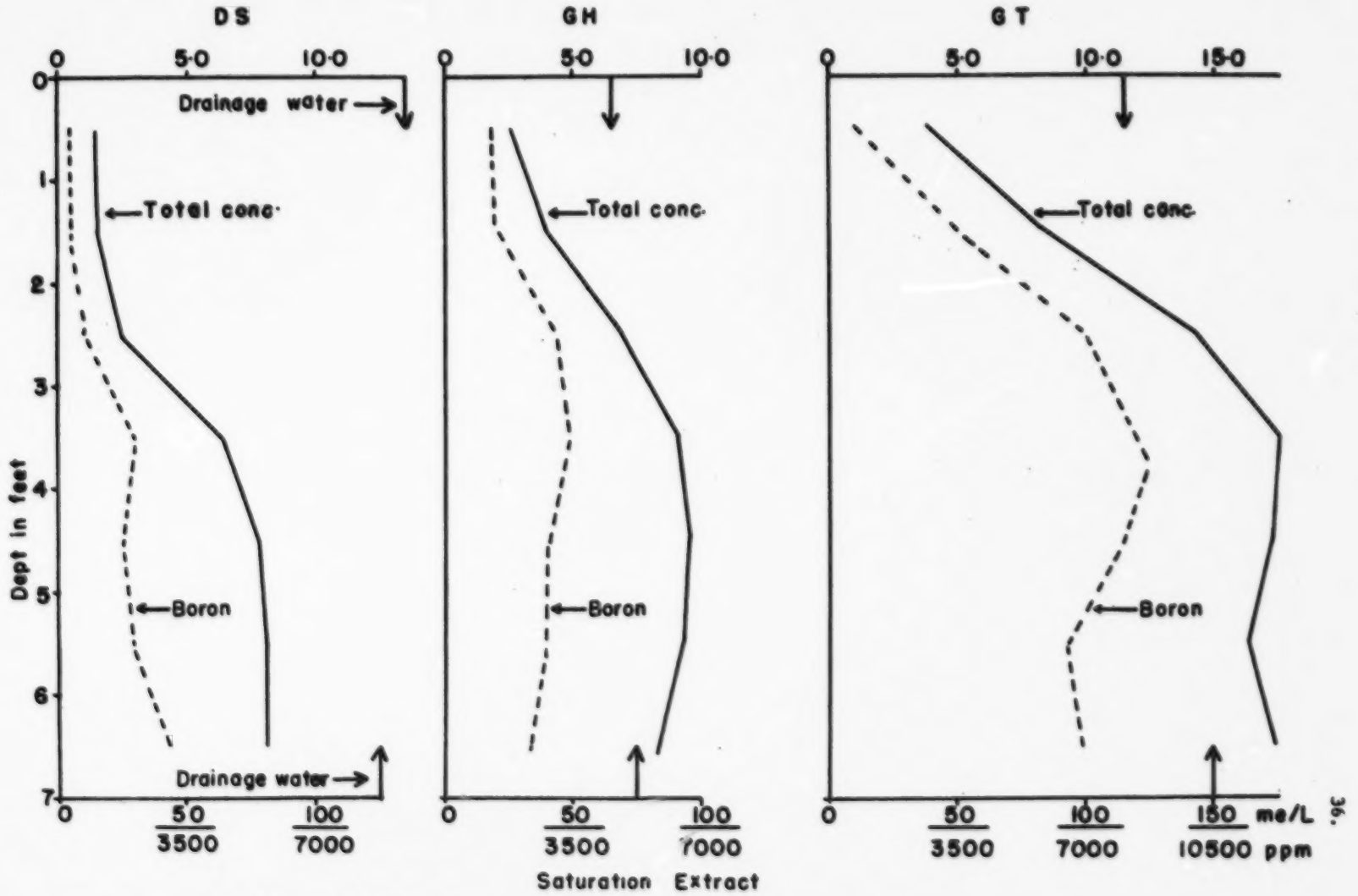

FIG. 9. Average concentration of soluble salts and boron in saturated extract of soil profiles and drainage water for 3 fields, DS, GH and GT.

Table 20

Conductivity (ECX10) of Saturation Extract and Crop Response

$ECX10^3$	Approx. conc. me/L	Crop Response
0-2	0- 20	Salinity effects mostly negligible
2-4	20- 45	Yields of very sensitive crops may be restricted
4-8	45-100	Yields of many crops restricted
8-16	100-220	Only tolerant crops yield satisfactorily
16+	220+	Only a few very tolerant crops yield satisfactorily

Table 21

Boron Toxicity in ppm of Saturated Extract for Sensitive to Tolerant Plants

Boron	ppm
< 1	low
1-3	slight
3-5	moderate
5-10	strong
> 10	very strong

The average concentration for total salts and boron in the effluent are also given in Figure 9 for the drain fields. The effluent concentration for GH and GT agrees fairly well with the saturation extract of the subsoil. This in part may be a coincidence, indicating the sampling locations represented the entire leaching field. However, the moisture content of the saturation extract is much higher (approximately 2 to 3 times) than the field moisture, Tables 4, 9, 11 and 16, whereas the saturated subsoil (in the water table) at field volume weight is somewhere between these values. The dilution of the field moisture increases the total amount of gypsum in solution, resulting in larger amounts of exchangeable ions from the exchange complex, whereas the highly soluble ions as chloride and nitrate are diluted in proportion to the increase in soil water. The bicarbonate ion is also lower in the saturation extract, 1.5 - 3.0 me/L than in the effluent of about 5.0. Lime is very slowly soluble and is ddependent on the partial pressure of CO_2, which is usually higher in the subsoil than in the atmosphere. Because the determination of cation exchange

capacity, exchangeable cations and equilibrium exchange constant are beyond the scope of this project, the concentration of total salinity for the saturation extract was not calculated to a field moisture content. For the DS field poor agreement is noted between the saturation extract of the soil and the effluent from the drain. Apparently the sampling locations did not represent the entire field, for example site 1 has no gypsum and site 4 is low, Figure 4. Nevertheless the concentration of the effluent indicates most of the drainage area contains gypsum comparing favorably with the analyses at sites 2 and 3, Table 3.

The soil samples collected represent the salinity in a small area compared to the entire field and, as noted above, salinity is recognized as being extremely variable from spot to spot. The location of the sampling area in relation to the drain lines will, to some degree, influence the leaching of the salt from the subsoil. The streamlines of saturated flow of the soil water to the drain are in a large measure unknown. The actual depth to which these streamlines go is uncertain, because the relation of vertical to horizontal hydraulic conductivity is not well defined and variable. Therefore, changes in soil salinity as determined by soil sampling may not be directly related to the composition of the drainage effluent.

The soluble salts of Cl and NO_3 at field moisture and in the drainage water are given in Figure 10 for the 3 drain fields. The soil profile of the DS field appears to be in equilibrium with the effluent after 8 years of leaching, whereas the GH field with a short period of leaching has a high accumulation of chlorides in the subsoil, and GT - where leaching has not occurred, but rather a lowering of the water table - has extremely high concentration of 120 me/L in the lower 4 feet of the subsoil.

With a continual dissolving of gypsum from the soil profile the total salt balance is very favorable, i.e., more salt is removed in the drainage effluent than is applied to the land in the irrigation water. Therefore, the chlorides were used as an indicator of salt balance and leaching requirements. The amount of effluent and tons of chloride applied in the irrigation water and removed by drainage is listed in Table 22. The DS field with 0.35 ac.ft/ac. or 19.4% of the irrigation wate/ used for leaching has a favorable salt balance. With 4.2 ac.in./ac. of drainage effluent, and ignoring winter drainage, it would require about 7 years for one displacement of the field moisture. Rice was grown on parts of the field for 3 years, 1962 to 1964, (Table 1) and undoubtedly considerable leaching occurred during this period

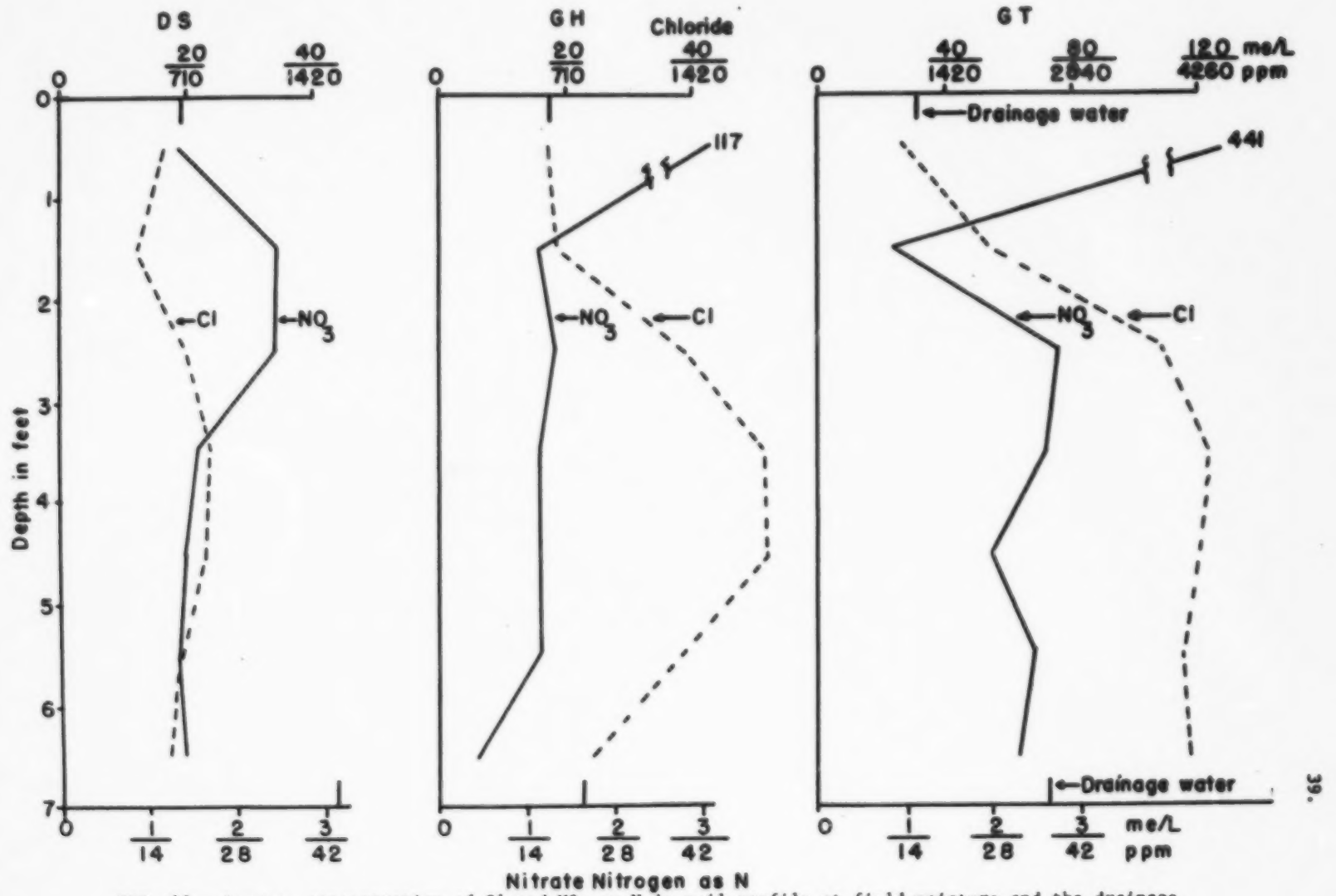

FIG. 10. Average concentration of Cl and NO_3 as N in soil profile at field moisture and the drainage water for 3 fields, DS, GH and GT.

when the soil was continually flooded. On the basis the field has reached a chloride balance, then the increase in chloride concentration from the irrigation water of 3.7 me/L should be directly proportional to the reduction in volume of water passing through the soil profile for a value of 19 me/L. This is in agreement with the average determined value of 19.8, Table 5.

Table 22

Drainage Effluent and Chloride Balance for Three Drain Fields

		Drainage Effluent			Tons Chloride			
Drain field	Date from - to	Total ac.ft.	ac. ft. per ac.	% of irrig. water	Influ-ent	Efflu-ent	Balance loss or gain	% loss or gain
DS	4/12 - 8/29	45.3	0.35	19.4	41.6	43.3	+1.7	+ 2.7
GH	3/18 - 8/29	55.2	0.22	6.4	154.9	48.0	-106.9	-69.0
GT	3/14 - 8/29	23.1	1.35*	64.7*	6.4	35.8*	29.4*	+459.4

* Residual soil water and chlorides from initially lowering the water table by recent drainage

With only 6.4% of the applied water appearing as effluent the GH field is in an unfavorable chloride balance. As a recently drained field there is a considerable accumulation of salines that should be leached, Figure 10. With a minimal amount of water applied to safflower in 1965 (Table 6) and for the crops in 1966, except the bell pepper field, which received 4.3 ac.ft/ac. (Table 7) and undoubtedly is the principal area providing the drainage water. The GT field received approximately the quantity of water required to grow the crop, 2.1 ac.ft/ac., while the drainage water represented 1.4 ac.ft/ac. or a lowering of the water table with the removal, in part, of the long time accumulation of salts.

Nitrogen relations and the leaching of nitrates. Nitrate nitrogen in the soil may be derived from 3 major sources: (1) soil organic matter including crop or plant residue, (2) legumes by symbiotic nitrogen fixation, and (3) the addition of fertilizers.

The percent nitrogen in the soil for DS and GH fields is given in Table 23 which includes total nitrogen - organic, ammonia, and nitrate, and well over 90% of the total nitrogen is usually organically combined (8).

Table 23

Total Nitrogen in Soil Profile for Fields DS and GH

Depth feet	DS Field		GH Field	
	%N	lbs. per ac. ft.	%N	lbs. per ac. ft.
0-1	0.07	2,380	0.08	2,720
1-2	0.03	1,020	0.06	2,040
2-3	0.04	1,360	0.04	1,360
3-4	0.03	1,020	0.04	1,360
4-5	0.02	680	0.03	1,020
5-6	0.03	1,020	0.03	1,020
6-7	0.02	680	0.03	1,020
7-8			0.02	680
Total		8,160		11,220

The principal legume grown in the area is alfalfa and the amount fixed in a year varies widely from only a few pounds to 300 or more (8). Usually the fixation varies inversely with the level of available nitrogen in the soil, and hence the nitrogen content of the crop may bear little relation to fixation. The nitrogen in the plant tops, varies from 50 to 66% which is removed as alfalfa hay (8).

Most of the nitrogen fertilizer applied is in the form of ammonia, nitrate or urea. The amount applied depends on a number of factors such as the crop history, the soil and the crop involved, but most of all on the judgment of the grower.

The major losses of nitrate nitrogen from the soil are: By removal in the harvested crop, denitrification, and leaching into the groundwater or drainage effluent. The principal crops grown in this locality, yields, percent nitrogen and the amount of nitrogen removed from the field by the harvested portion of the crop are given in Table 24. The Agricultural Extension Service estimated the expected yields for this locality. The variation in nitrogen content of a crop is small and an average value

is listed in Table 24 (9). The nitrogen removed between the harvested crops varies approximately 100%, with the smallest amount for safflower and the largest for milo.

Denitrification commonly refers to the biological reduction of nitrates and nitrites to volatile gases, usually nitrous oxide and/or molecular nitrogen (8). In recent years it has been recognized this may involve a combination of chemical and biological reactions. Denitrification is associated with anaerobic conditions or where the oxygen supply is low, as high water tables and wet conditions where poor aeration occurs. It has also been shown that a source of energy is required, such as readily decomposable organic matter for the reduction of nitrates. Although denitrification is widely recognized as a common soil process direct evidence concerning its occurrence in field soils remains limited because of the experimental difficulties involved in obtaining such evidence. This is an area requiring more investigation and research.

Nitrates are soluble and readily move with the percolating water and if the above processes do not interfere they will eventually appear in the ground water or the drainage effluent. The three drainage fields selected in this locality were known to contain an appreciable amount of nitrate in the drainage effluent and do not necessarily reflect other drainage systems in the San Joaquin Valley as some are relatively low. (13)
The

The fields were sampled at two dates, a month or more apart with intervening irrigations and the nitrates in the soil profile are indicated in Figure 11.

Table 24

Crop Yields and Nitrogen Removed from the Field by Harvesting

Crop	Yield lbs. per acre	%N	N removed by crop
Barley	5,000 - 5,500	1.50	75 - 82
Cotton-seed	2,000 - 2,500	3.70	74 - 92
Milo	5,500 - 6,500	1.80	99 - 117
Rice	4,000 - 5,000	1.26	50 - 63
Safflower	1,800 - 2,400	2.61	47 - 63

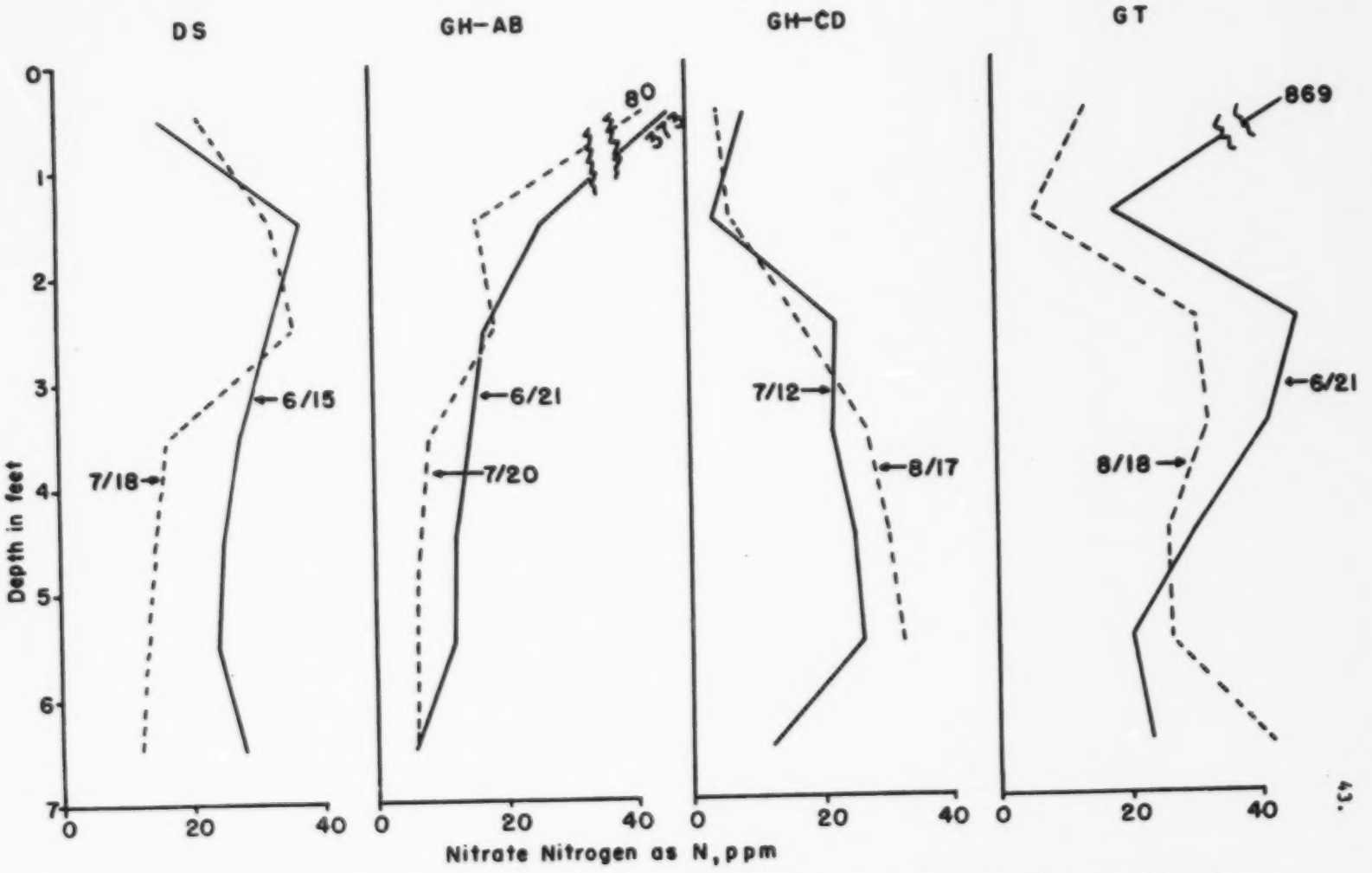

FIG. 11. Nitrogen as nitrate in the soil profile at field moisture for two sampling dates and 4 fields.

Field GT shows some decrease in nitrates at the second sampling for the surface layers of soil, but is not exemplified in the other fields. With the exceptions of DS drainage system the nitrates in the field moisture of the subsoil are in general agreement with the concentration in the drainage effluent, Figure 10. The nitrate concentration in the effluent from the DS field is much higher than in the field moisture, although the equally soluble chloride ion has reached an equilibrium between field moisture and the effluent, which indicates nitrates may be originating from an accumulation in the deeper ground water even though two samples from the surface of this water table show lower nitrates than in the effluent, Table 5. Since 1962 the effluent from DS field has been high in nitrates (13 - system No. 6). Nitrates in the ground water may have accumulated not only from fertilizer in which large quantities in recent years were applied to this field, Table 1, but originally from the non-irrigated virgin soil, as shown by Dyer (6) and others (12) to be exceptionally high, and by the analyses of the GH-Vi area, Table 18, where the ground water contained over 6 me/L. The exception is the PG area where the soil is sandier and located some distance from this high nitrate area.

An estimation of the amount of nitrogen applied, removed by the crop and in drainage effluent for the 3 drain fields, is given in Table 25. This table does not include the natural nitrification taking place in the soil which will vary in amounts depending on a number of factors in the soil influencing nitrification. Occasionally crops are grown without fertilizer indicating an appreciable amount natural nitrification is occurring in these and other soils (12). Other work (10) would indicate 40 to 80 pounds of nitrogen as nitrates may be produced in 5 feet of soil during the winter and spring months. Consequently, the nitrogen losses are far greater than is indicated in Table 25 for DS and GH fields, whereas, for GT field the large amount removed in the drainage water is probably from the nitrates of the native soil plus some from fertilizer.

The loss in nitrate-nitrogen must be due in part, or entirely, to denitrification. The requirements to bring this about are not documented for water tables in the subsoil and additional research is required to delineate the factors involved. In contrast to the fields under investigation many other drain fields following essentially the same fertilizer and cropping practice have relatively low nitrates in the draiage effluent.

Table 25

Nitrogen Fertilizer Applied and Removed
in the Harvested Crops and Drainage Water

Field	Pounds of Nitrogen			
	Applied as Fertilizer	Removed by Crop	Drainage Water[3/]	Loss or Gain over Amount Applied
DS[1/]	169	82.2	42.4	-44
GH[2/]	97	63.5	13.7	-20
GT[2/]	105	71.5	137.3	+104

1/ 5 year average

2/ 4 year average

3/ For the summer of 1966

The DS field received more nitrogen fertilizer and the loss to the drain was greater than for GH, Table 25, however, the amount of drainage from DS was larger than from the GH field - 19.4% to 6.4% of the applied water, respectively. Investigation of a large number of drains in the San Joaquin Valley indicates an average discharge through the drains from 3 to 18% of the water applied depending on the crop grown (11). The rapidity of leaching or percolating waters may have a definite influence on denitrification.

The role nitrogen plays in relation to its concentration in the drainage water is not entirely understood, and is complicated by many unknown factors. Just a few are: (1) Large quantities of water must be used for displacing the soil solution - about 30 inches - and may require many years before the soil solution is displaced once. (2) The amount of nitrogen that may be temporarily tied up in the decomposition of carbonaceous material. (3) Denitrification under anaerobic conditions as the water table is approached and in the water table itself. These are only a few of the areas requiring additional investigation and research.

SUMMARY AND CONCLUSIONS

The total salts of the drainage effluent will remain high, about $10ECX10^3$ (125 me/L), because of large amounts of gypsum in the soil above the drain lines. At the present rate of leaching many years will be required to dissolve and remove this gypsum from the soil profile. However, the leaching time can be accelerated by applying large amounts of water to the land, decreasing irrigation efficiency and increasing the amount of drainage water for disposal.

Because boron is partly fixed in the soil, the high concentrations in the profile will also require copious quantities of leaching water to decrease it to a low level for sensitive crops.

Based on the chloride concentration, the DS field drained for 8 years with 19% of the irrigation water appearing as effluent, 1966, has reached a salt balance in regard to the irrigation water.

The nitrate-nitrogen in the effluent for the three drained areas is principally from three sources: (1) soil organic matter, (2) originally in the soil profile or ground water before irrigation, and (3) fertilizers (legumes have not been grown in these fields for a number of years). In contrast, the losses of nitrate-nitrogen from the soil and water table may be considered in three general categories: (1) removed in the harvested crop, (2) by denitrification, and (3) in the drainage water. A number of parameters for the above conditions are unknown or may be only very roughly estimated, such as the amount of nitrates derived from the organic matter, or in the native soil or water table prior to farming, and for losses, the amount of denitrification occurring with high water table soils. Consequently, the source of nitrate-nitrogen in the drainage water is difficult to determine and additional research is required to delineate the many factors influencing the accumulation and/or loss of nitrates under high water table conditions. Nevertheless the DS field having a chloride balance and receiving large applications of fertilizer, it can be assumed the high nitrate-nitrogen content of the drainage water is in a large part from fertilizers, notwithstanding large amounts were probably denitrified. This conclusion is not valid for the recently drained GH and GT fields because the nitrate sources are unknown as they have been accumulating in the subsoil and ground water for a long period of time.

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